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# USSR Report

ENGINEERING AND EQUIPMENT

No. 92

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ENGINEERING AND EQUIPMENT

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NUCLEAR ENERGY

UDC 621.311.08

PECULIARITIES OF REGULATING ATOMIC POWER SETS DURING SYNCHRONOUS OSCILLATIONS IN POWER SYSTEM

Moscow ENERGOMASHINOSTROYENIYE in Russian No 5, May 82 pp 10-11, 14

GOLOVACH, Ye. A., candidate of technical sciences, GUREVICH, M. Kh., candidate of technical sciences, KIM, V. Ye., engineer, and SEN'KIN, V. I., candidate of technical sciences

[Abstract] Regulation of turbines in atomic power sets during synchronous oscillations in the power system is analyzed on basis of a mathematical model describing the electric generator, the turbine with speed regulator and proportional-integral power regulator, the steam generator, and the nuclear reactor. Calculations are made specifically for a VVER-1000 water-moderated water-cooled power reactor and a K-1000-60/1500 turbine. The results indicate how strongly the dynamic system asymmetry and the short time constant of the steam separator-preheater set affect turbine performance. The results are for design of an automatic regulation system to ensure maximum reliability, which requires variable width of the insensitivity zone at the input of the turbine regulation system. Figures 4, references 5 Russian.  
[2-2415]

UDC 621.311.25.621.039

STRESSED-STRAINED STATE AND VIBRATION RESISTANCE OF COLLECTORS IN TURBINE SETS WITH RBMK-1000 WATER-GRAPHITE CHANNEL REACTOR IN LENINGRAD, KURSK AND CHERNOBYL' ZES AS TYPICAL EXAMPLES

Moscow ENERGOMASHINOSTROYENIYE in Russian No 5, May 82 pp 7-9

SHUL'TSEV, D. N., candidate of technical sciences, YEGOROV, M. F., candidate of technical sciences, KUZ'MIN, Yu. S., engineer, and SIDOROV, A. A., engineer

[Abstract] The coolant circulation system for an RBMK-1000 water-graphite reactor (four such reactors in the Leningrad AES, two in the Kursk AES, two

in the Chernobyl' AES) includes two-loop multipass forced circulation. In each loop there is a head collector and a suction collector. These collectors as well as the piping are made of 22K low-carbon steel tubes with 08Kh18N10T stainless steel cladding. The design of collectors and piping (750 mm OD, 38-53 mm wall thickness) is based on analysis of initial stresses, stress self-compensation, static stresses and strains under load and dead weight, and vibrations in operation. Calculations reveal that most critically stressed are the joint connecting the suction line to the pump and the joint connecting the elbow to the horizontal segment of the head line. The best piping layout, from standpoint of stress self-compensation, is that for the second-generation Leningrad AES. There the lower critical frequencies lie within the 2.6-5 Hz range and spring supports change the upper critical frequencies by not more than 0.3 Hz. Figures 2, table 1, references 6 Russian. [2-2415]

UDC 621.039.534

EQUATIONS OF EQUILIBRIUM DISCHARGE FLOW AND STAGNATION PARAMETERS IN TURBINES OF NUCLEAR POWER PLANTS WITH DISSOCIABLE NITROGEN TETROXIDE

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 43, No 2, Aug 82  
(manuscript received 30 Mar 81) pp 201-209

ORUDZHALIYEV, E. A., Azerbaijan Institute of Petroleum and Chemistry  
imeni M. Azizbekov, Baku

[Abstract] General expressions for isentropic and adiabatic enthalpy drops across nozzle array and across runner blading as well as inside the turbine are modified so as to apply to dissociable nitrogen tetroxide in the  $N_2O_4 \rightleftharpoons 2NO_2 \rightleftharpoons 2NO + O_2$  system used as working substance in nuclear power plants. Other parameters are also modified, namely compressibility and its partial derivatives with respect to temperature and pressure as well as effective compressibility at sections 0,1,2 at temperature  $T_0, T_1$  for insertion into the equations for equilibrium discharge velocity and mass rate. Stagnation temperature and pressure are calculated on this basis. Critical temperature and pressure are then calculated from known relations between them and corresponding stagnation parameters at Mach number  $M = 1$ . Numerical values are obtained and compared with those for an ideal gas. Tables 2, references 3 Russian.

[11-2415]

NON-NUCLEAR ENERGY

UDC 628.169(088.8)

HYGROSCOPIC EVAPORATORS WITH CONTACT DEVICES

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 2, Feb 82 (manuscript received 19 Jan 81) pp 121-122

TAUBMAN, Ye. I., candidate of technical sciences, KALISHEVICH, Yu. I., engineer, and SAVINKIN, V. I., Odessa Technological Institute of Refrigeration Industry

[Abstract] Hygroscopic evaporators using liquid solutions combine simplicity of construction with high reliability, they do not require vacuum equipment and they utilize low-potential dumped heat. In order to make such evaporators practicable, it is necessary to increase their efficiency and reduce scale formation on heat exchange surfaces at high concentrations of the solute. This can be achieved by contact heating of the liquid solution with a gas. A typical system operating according to this principle consists of two loops, an evaporator loop and a "liquid-gas" contactor loop, coupled directly and through a condenser-heater set, a gas injector in each loop, a preheater in the contactor loop, a solution feed pump, a solution circulating pump, and a distillate pump. An analysis of the operating thermodynamic cycle reveals ways to improve the performance of this device, such as multistaging with better indicators than those of a single adiabatic stage. Article was presented by Chair of Engineering Thermodynamics. Figures 2, references 2 Russian.

[4-2415]

UDC 621.565.94;621.311.15,026.44

INSTANT-BOILING EVAPORATORS FOR 500 MW AND 800 MW POWER SETS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 8, Aug 82 pp 34-36

BERSENEV, V. A., engineer, and GOLUBEV, Ye. K., candidate of technical sciences

[Abstract] Instant-boiling evaporators require less severe softening treatment of makeup feed water prior to distillation than do surface-type

evaporators subject to scale deposit. They consist of four evaporator stages assembled in a vertical cylindrical vessel together with an ejector, a pre-heater for circulating water, a pump for circulating water and a pump for distilled water. Each evaporator stage consists of a boiling chamber, a separation chamber and a condensation chamber. Condenser tubes as well as rinse plates and louvered separators are made of stainless steel, housing and all other components are made of boiler-grade carbon steel. All auxilliaries are standard components, such as model PN preheaters manufactured at the "Krasnyy Kotel'shchik" plant. Instant-boiling equipment is installed and operating in 500 MW and 800 MW power sets. Figures 2, tables 3.  
[3-2415]

INDUSTRIAL TECHNOLOGY

UDC 621-503.2

METHOD OF EVALUATING EFFECTIVENESS OF ON-LINE CONTROL OF INDUSTRIAL-ROBOT PERFORMANCE

Moscow MASHINOVEDENIYE in Russian No 3, May-Jun 82  
(manuscript received 1 Jul 81) pp 17-21

KOLISKOR, A. Sh. and SERGEYEV, V. I., Moscow

[Abstract] On-line control of industrial-robot performance is evaluated on an integral basis, without analysis of the interrelations between performance and correction parameters. The method of predicting the effectiveness of such a control rests on stochastic relations governing the trajectory of tongs during various cycles of robot operation. Deviation of the actual trajectory from the programmed one serves as performance criterion. The motion of typical tongs with six degrees of freedom, as an example, is defined in Cartesian systems of coordinates with Euler angles. A mathematical model of random and systematic errors is constructed, both groups of errors affecting the trajectory along a given coordinate. The corresponding dispersions of deviations are calculated accordingly, through separation by the method of differences and subsequent summation. All dispersions are evaluated comparatively, as fractions of the total, for an indication of most effective ways to improve the accuracy of motion in a given degree of freedom. This method of calculating the dispersions also reveals the maximum deviations practically allowable with full compensation of systematic errors. Data on errors of motion needed for such control are obtainable from instantaneous Cartesian or polar coordinates of three points of the tongs. One can then determine the necessary number of check points along the trajectory to ensure sufficient information content in these data. Figure 1, references 5: 4 Russian, 1 Western.

[24-2415]

UDC 621.822.5

CRITICAL PARAMETERS OF CYLINDRICAL GAS BEARINGS WITH DISCRETE INJECTION

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 82  
(manuscript received 26 Feb 81, after completion 1 Dec 81) pp 97-103

KARPOV, V. S. and GRUDSKAYA, Ye. G., Leningrad

[Abstract] The critical parameters of gas bearings, corresponding to resonance in the "shaft-lubricant film-bushing" system and the stability limit of the shaft, are calculated on the basis of the system geometry and known reaction forces. The gas bearing is assumed to be cylindrical, with discrete injection through a row of orifices as an isentropic process. Calculations are based on the Reynolds integral equation for pressure, which is solved numerically by the finite-difference method with an approximating rectangular grid. The results yield the critical injection pressure and the threshold shaft mass, depending on the number of feed orifices, on the coefficient of internal compensation, on the gas properties and on the injection system parameters. Figures 2, table 1, references 6: 5 Russian, 1 Western,  
[22-2415]

UDC 534.14

EXCITATION OF VIBRATIONS IN MECHANICAL SYSTEM WITH CONTROLLABLE PARAMETERS

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 82  
(manuscript received 4 Jun 81) pp 10-19

GERTS, M. Ye., Moscow

[Abstract] The feasibility and advantages of substituting autoresonant excitation for a periodically variable excitation in a mechanical system are considered, in a system with one degree of freedom, viscous friction, and a nonlinear elasto-dissipative process. The dynamic model of such a machine consists of a servo element with mass  $M$  coupled to the base through both a spring with stiffness  $C$  and a rod of length  $L$  hinged to that base. Transfer from parametric excitation to autoresonant excitation involves replacing the force  $U^*(t)$  acting on the mass and constrained in absolute magnitude with a force  $U^* = R[x(t), \dot{x}(t), \ddot{x}(t)]$  ( $x$ - space coordinate of motion,  $t$ - time) so that the condition of stability will be satisfied during fluctuations of the object parameters or of the working process. The corresponding equation of motion  $M\ddot{x} + Cx + \emptyset^*(x, \dot{x}) + U^*x/L = 0$  is solved for calculation of both parametric and forced vibrations as well as transient processes. The general procedure is demonstrated on a vibratory system with cubic nonlinearity of the elasto-dissipative process, describable by the equation  $M\ddot{x} + 2b\dot{x} + Cx + \gamma x^3 = U_1$ , with either autoresonant excitation  $U_1 = d_1 \text{sign } x(t-\tau)$  or

periodic-force excitation  $U_1 = d_1 \text{sign} \sin(\omega t - \phi)$ . In this case the transient period is always shorter and, consequently, the response speed higher with autoresonant excitation. Figures 5, references 11: 10 Russian, 1 Western. [22-2415]

UDC 621.822.5

#### STABILITY OF SPHERICAL GAS BEARING

Moscow MASHINOVEDENIYE in Russian No 4, Jul-Aug 82  
(manuscript received 10 Aug 81) pp 82-85

KARPOV, V. S. and PROKULEVICH, L. A., Leningrad

[Abstract] Stability limits of spherical gas bearings with eccentric lubricant layer are determined from the vector equation of motion for the center of inertia of an ideally balanced rotor under a constant force and from the Reynolds equation for pressure. The dynamic-stiffness matrix is evaluated and the reaction force of the gas layer as a function of time is calculated by a method applicable to a rotor with unbalance and assuming equal vibration amplitudes along all coordinate axes. Numerical data have been obtained for the threshold mass and frequency at the stability limit for axial and radial displacements of the rotor shaft respectively. Figures 3, references 4 Russian. [23-2415]

UDC 621.822.5

#### DAMPING TORSIONAL VIBRATIONS OF SHAFT BY VISCOUS FRICTION

Moscow MASHINOVEDENIYE in Russian No 4, Jul-Aug 82  
(manuscript received 23 Oct 80, after completion 9 Mar 82) pp 74-76

VOLKOV, A. A. and POLUYANOV, L. V., Kuybyshev, Moscow

[Abstract] Damping of torsional vibrations of shafts with thick-film lubrication is analyzed on the basis of the Zhukovskiy-Chaplygin theory. Non-periodic motion of the film in the bearing clearance is taken into account by addition of a corresponding transient term to the biharmonic equation for the flow function and by appropriate correction of the boundary condition at the moving surface. The damping torque is calculated for low-frequency and high-frequency vibrations, the former according to a simple relation and the latter by the method of singular perturbations, with an analog of the Struhal number as characteristic parameter. The results reveal that angular precession increases the damping torque on average. References 3 Russian. [23-2415]

VECTOR EQUATIONS DESCRIBING INTERDEPENDENCE OF KINEMATIC PARAMETERS OF SPATIAL MECHANISMS

Moscow MASHINOSTROYENIYE in Russian No 4, Jul-Aug 82  
(manuscript received 19 Mar 80, after completion 20 Jan 81) pp 54-58

LEBEDEV, P. A., Leningrad

[Abstract] The author has developed a vector method of kinematic analysis and of solving problems in kinematics of bar mechanisms. It is based on determining the position of spatial mechanisms with lower-order kinematic pairs. It utilizes the property of direct operator calculus that vector multiplication can be represented by linear combinations of the multiplicand vectors. It obviates the need for solving high-degree algebraic polynomial equations. The five-step algorith, based on Kotel'nikov's transference principle, yields the interdependence of geometric and kinematic parameters of a complex mechanism in explicit form. It is demonstrated on a six-axis spatial mechanism with rotational kinematic pairs. Figure 1, references 15: 10 Russian, 5 Western.  
[23-2415]

STEREOTYPIC MOTIONS OF INDUSTRIAL ROBOTS

Moscow MASHINODEDENIYE in Russian No 4, Jul-Aug 82  
(manuscript received 11 Feb 81) pp 44-53

TYVES, L. I. and PURTSELADZE, G. K., Moscow

[Abstract] Stereotypic motions of industrial robots are classified in two ways, according to the geometric elements of the robot skeleton and of the ambient medium in which they move, or according to the stipulated constraints on that motion such as coincidence (point), attendance (straight line or plane curve), and perpendicularity. Synthesis of kinematic links to satisfy these constraints is based on the corresponding equations of motion in generalized coordinates and their explicit form for specific elements. When the equations are linear, only reducers and differentials are required. When the equations are nonlinear, one can expand them in series with respect to harmonic functions and use elements of sine-cosine mechanisms. The analysis of motion, steady-state and transient, with subsequent synthesis of the linkwork for an anthropomorphic structure are demonstrated on a "hand" consisting of a seven-element open kinematic linkwork. Included is the consideration of self-braking effects and their compensation as well as control of the sign of torques produced by auxilliary drives in the case of nonlinear equations of motion. Figures 5, table 1, references 6 Russian.  
[23-2415]

MODELING MECHANICAL SYSTEMS OF INDUSTRIAL ROBOTS ON DIGITAL COMPUTER

Moscow MASHINOVEDENIYE in Russian No 4, Jul-Aug 82  
(manuscript received 2 Apr 81) pp 38-43

VOSKRESENSKIY, V. V., DOROFEEYEVA, L. G. and KABANOV, A. N., Moscow

[Abstract] Two problems of modeling industrial robots are considered, namely mathematical description of mechanical systems with many degrees of freedom and analytical stipulation of the trajectory of tongs in an absolute system of coordinates with subsequent transformation to generalized coordinates of the mechanism. The first problem is illustrated in the specific case of a robot mechanism consisting of an open kinematic linkwork with five degrees of freedom, this linkwork being converted to an equivalent one with only class-5 rotational or translational pairs. The second problem is treated generally, in terms of matrix calculus as a basis for calculating the motion of linkwork elements. The algorithms formulated for this purpose are a POSITION block for determining the position of an element and a KINEMATIC block for determining its velocity and acceleration. The algorithm for analyzing the dynamics of a complex mechanical system has been formulated in a DINAMIC block, all three blocks being included in the MEXM head program written in FORTRAN and implemented on a YeS-1022 computer. Programmed control of the motion has been formulated in a CONTROL block with parametric description of the mechanism and with transformation of coordinates through matrix inversion, which impart to it some degree of versatility. Practical application of the MEXM head program, with mechanical characteristics of the system and dimensions of all quantities stipulated SI units, is demonstrated on the PR-35 industrial robot. Here a CONTROL block subdivides a trajectory into three intervals: acceleration, constant velocity, deceleration. Arcs of circles are approximated with eight polynomial segments each and the transformation of coordinates is checked for accuracy by calculation of displacements and velocities in both systems of coordinates. Figures 3, tables 2, references 6 Russian.  
[23-2415]

## TURBINE AND ENGINE DESIGN

UDC 681.521.34;621.452

### DESIGN OF VIBRATION SUPPRESSORS FOR DAMPING PRESSURE FLUCTUATIONS IN GAS TURBINE ENGINE CONTROL SYSTEMS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 7, Jul 82 (manuscript received 6 May 81) pp 65-68

SHORIN, V. P., doctor of technical sciences, GIMADIYEV, A. G., candidate of technical sciences, docent, and SHAKHMATOV, Ye. V., engineer

[Abstract] A problem in control of gas turbine engines is considered, namely selection and design of a vibration suppressor for adequate damping of pressure fluctuations in the control system within a not excessively long transient period. The system is represented as one consisting of three elements, vibration source - damper - load in series, and its performance parameters are calculated on basis of the frequency characteristic of its transfer function. The results, with proper simultaneous constraints on transient period and insertion loss factor, are implemented in the design of such a damper in the form of an acoustic filter consisting of a throttle on a tubular shaft and a nut around a nipple. When a sufficiently short transient period cannot be attained even with a narrow-band filter, then another type of vibration suppressor must be selected. Figures 3, reference 1 Russian.

[5-2415]

UDC 621.438

### APPROXIMATE CALCULATION OF VARIABLE FORCES ACTING ON RUNNER BLADES IN COOLED GAS TURBINES

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 7, Jul 82 (manuscript received 17 Jun 81) pp 84-88

FEDOROV, R. M., doctor of technical sciences, professor, and TYUGASHOV, P. F., engineer

[Abstract] Transient aerodynamic forces acting on runner blades in a cooled gas turbine stage are calculated on the basis of an approximate linear model.

The calculation accounts for generally nonuniform circumferential distributions of temperature  $T_0^*$  and pressure  $p_0^*$  before the nozzle inlet as well as formation of short-period trails behind the runner blades. Both distributions are assumed to be known, also the runner speed and the geometrical characteristics of runner and nozzle blades. Pressure fluctuations are negligible and temperature fluctuations do not exceed 10%. Calculations are made by the method of small deviations, all parameters of the gas stream being expressible in terms of three: mean temperature  $T_{0,m}^*$ , mean pressure  $p_{0,m}^*$  and pressure  $p_2$  at exit from the runner. Polynomial expressions are constructed for static (average) forces and the velocity profile, from which dynamic forces and their distribution due to nonuniformity of the gas stream before the nozzle can then be determined. Figures 3, references 4 Russian.

[5-2415]

## NAVIGATION AND GUIDANCE SYSTEMS

UDC 531.383

### APPLICABILITY OF QUASI-STATIC METHOD TO ANALYSIS OF DYNAMICS OF GYROSCOPE WITH FLUID SUSPENSION

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 82 (manuscript received 14 Apr 80) pp 10-20

GORODETSKIY, O. M. and KLIMOV, D. M., Grodno; Moscow

[Abstract] Transient isothermal laminar flow of a viscous fluid in a cylindrical hydrodynamic gyroscope suspension is analyzed by the quasi-static small-parameter method. With end effects disregarded, the problem reduces to flow of a fluid within the space between two eccentric circles, cross sections of the housing and of the float inside. This flow is described by the Navier-Stokes equations and the continuity equation in polar coordinates, all partial differential equations. The boundary conditions are adhesion of the fluid to housing and float surfaces. Integration of these equations, containing nonlinear terms and involving one movable boundary (float), is facilitated by an expedient change of variables and subsequent conversion to ordinary differential equations. The solution yields expressions for the components of reaction forces and their moment developed by the fluid. Figure 1, tables 3, references 16 Russian.  
[6-2415]

UDC 531.38

### OBSERVABILITY OF PARAMETERS OF INERTIAL NAVIGATION SYSTEM FOR CORRECT VEERING

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 82 (manuscript received 12 Nov 80) pp 21-26

MOROZOV, V. M., MATASOV, A. I. and SHAKOT'KO, A. G., Moscow

[Abstract] A two-component inertial navigation system with horizontal platform and azimuthal degree of freedom is considered where external means

are used as sources of data on altitude and vertical velocity. Errors of this system are used as sources of data on altitude and vertical velocity. Errors of this system are characterized by three vectors of small angular displacement, of the model trihedron and the instrument trihedron relative to each other and each relative to the ideal trihedron. The corresponding differential equations of errors are solved for the latter so as to indicate their observability on the basis of measurement of related parameters, after an appropriate change of both "slow" and "fast" variables characterizing the error components. An algorithm is constructed on this basis for correct veering of such a navigation system. References 5 Russian.

[6-2415]

UDC 531.386

#### STABLE MOTION OF CERTAIN GYROSCOPIC SYSTEMS AT RESONANCE

Moscow IZVESTIYA AKADEMII NAUK SSSR; MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 2 Apr 80) pp 69-72

FILATOV, O. P. and KHAPAYEV, M. M., Moscow

[Abstract] Two kinds of gyroscopes are considered, one in a contactless suspension constituting a system with three resonance frequencies and one in a universal joint. Stability of their motion at resonance is analyzed without assuming a small rate of change of phase mismatches in the vicinity of steady-state solutions. Calculations are based on the corresponding equations of motion. The results are applied to one extreme case of nutational oscillations, namely those with near-zero amplitude, the highly nonlinear case of near-unity amplitude having been considered elsewhere.

References 6 Russian.

[6-2415]

UDC 531.383

#### CONTROLLING SYSTEMS OF POWER GYROSCOPES WITH TWO DEGREES OF FREEDOM AND PARALLEL PRECESSION AXES

Moscow IZVESTIYA AKADEMII NAUK SSSR; MEKHANIKA TVERDOGO TELA in Russian  
No 3, May-Jun 82 (manuscript received 3 Sep 80) pp 14-20

VASIL'YEV, V. N., Moscow

[Abstract] A system of  $n$  identical gyrodynes with arbitrarily oriented precession axes is to be controlled from a station. The control torque vector is a function of precession angles and velocities. In an inertial system of three space coordinates such a control, based on tracking the precession velocities, is described by a system of three equations, this

number of equations being smaller than the number of unknown velocities in the case of more than three gyrodynes. In that case the problem can be solved by converting to another system of equations for groups of at least two gyrodynes. This method is applied to a typical group, gyrodynes with parallel precession axes and constituting an autonomous servomechanism which produces two control torques about two station axes. This torque depends not only on the angular momentum but also on the sign of its first time derivative. A control algorithm for a typical group of three such gyrodynes is constructed so as to ensure the possibility of varying the angular momentum from zero in any direction to the circle with a radius corresponding to the number of gyrodynes in the group, in this case specifically three. Figures 6, references 4 Russian.

[7-2415]

UDC 531.55

#### OPTIMUM CONTROL OF ROCKET THRUST IN ATMOSPHERE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 3, May-Jun 82 (manuscript received 17 Jun 80) pp 21-27

KIFORENKO, B. N., Moscow

[Abstract] Controlling the thrust of a rocket engine in the atmosphere is considered, this thrust being smaller than in vacuum by an amount proportional to the air pressure. Optimum control with a relay characteristic under conditions of jump-wise density rises in the nozzle is determined for a Laval nozzle, in the one-dimensional lossless approximation and taking into account the flowrate of reaction mass. With inertia and back pressure, optimum control becomes a limit control with a Pontryagin extremal trajectory and control of variable-thrust travel reduces to control of the optimum sliding mode with finite number of alternations. Figures 3, references 15: 12 Russian, 3 Western.

[7-2415]

UDC 531.1

#### FAST ROTATION OF HEAVY GYROSTAT ABOUT FIXED POINT IN RESISTING MEDIUM

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82 (manuscript received 14 Jan 80) pp 102-107

AKULENKO, L. D., Institute of Problems in Mechanics, USSR Academy of Sciences, Moscow; LESHCHENKO, D. D., Odessa Technological Institute of Refrigeration Industry

[Abstract] Equations of motion are derived for an asymmetric heavy body with spherical cavity containing high-viscosity fluid, rotating at high speed about

a fixed point in a weakly resisting medium. The position of the body is defined in three Cartesian systems of coordinates with common origin at the center of mass: one stationary, one aligned with the vector of angular momentum, one aligned with the principal axes of inertia. The small parameters are  $mga/T_0 \ll 1$  ( $m$ - mass of body,  $a$ - distance from center of mass to fixed point,  $g$ - acceleration of gravity,  $T_0$ - initial kinetic energy) and  $||I||$ - norm of matrix of constant drag coefficients,  $G_0$ - initial angular momentum). The equations are solved for nonresonant Euler-Poinsot motion, first without perturbation and then transient after a small perturbation, where  $G, \delta, \lambda, T$  are slow variables ( $\delta, \lambda$ - angles defining orientation of the axes of the stationary system of coordinates relative to corresponding axes of the other two systems respectively) and the Euler angles  $\theta, \phi, \psi$  (between corresponding axes of the other two systems of coordinates) are fast variables. Application of the method of averaging yields an expression containing complete elliptic integrals of first and second kinds and, after subsequent transformations, equations for the first derivatives of sought variables with respect to time. The authors thank F. L. Chernous'ko for discussions and helpful suggestions. Figures 3, table 1, references 14 Russian.

[17-2415]

HIGH-ENERGY DEVICES, OPTICS AND PHOTOGRAPHY

UDC 621.378.325

SINGLE-FREQUENCY MONOPULSE LASER ON NEODYMIUM PHOSPHATE GLASS WITH ACTIVE Q-SWITCHING

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
(manuscript received 24 Aug 81) pp 199-202

LEONT'YEV, V. M., SITNIKOV, S. F. and SOKOLOV, V. I., Institute of Atomic Energy, Moscow

[Abstract] A single-frequency monopulse laser on neodymium phosphate glass with electrooptical Q-switching and selection of axial modes has been built which is as reliable as one with passive shutter. Its optical system consists of a dielectric mirror with reflection coefficient  $R = 0.99$ , a DKDP crystal acting as both shutter and polarizer, a cell containing an IFP-800 pump and a rod of GLS-21 neodymium phosphate glass as active medium inside a silver-coated quartz reflector, a diaphragm, and a dielectric mirror with reflection coefficient  $R = 0.2$  which reflects one part of the laser beam into a photo-receiver through a biconcave lens and a set of light filters and transmits the other part through a Fabry-Perot interferometer to a resonator reflector formed by a single 10 mm thick plane-parallel glass plate and a stack of two glass plates for selection of axial modes. The laser produces emission pulses of 20 mJ energy and 40 ns duration, the second-harmonic spectrum not wider than  $4 \cdot 10^{-3} \text{ cm}^{-1}$  at wavelength  $\lambda = 1.054 \mu\text{m}$  and the mode separation in an  $L = 1 \text{ m}$  long resonator equal to  $1/2L = 5 \cdot 10^{-3} \text{ cm}^{-1}$ . Two types of photo-receiver can be used for synchronization: either a phototransistor KT-809 (photothyristor KU-203) which triggers the shutter through a pulse shaping line and a hydrogen-filled thyratron TGI2-130/10, or a coaxial photocell FEK-15 which triggers the shutter directly. The performance of both is equivalent, but the radiation contrast (ratio of pulse energy to prepulse energy) is sharper with a phototransistor or photothyristor. Figures 3, references 16: 13 Russian, 3 Western.

[21-2415]

## CONTINUOUS-DUTY ELECTRON GUN WITH PLASMA CATHODE OF LARGE AREA

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
 (manuscript received 27 Jul 81) pp 178-180

KREYNDEL', Yu. Ye., MARTENS, V. Ya., S"YEDIN, V. Ya. and GAVRINTSEV, S. V.,  
 Tomsk Institute of Automatic Control Systems and Radioelectronics

[Abstract] A continuous-duty electron gun has been built that contains a plasma cathode sufficiently large for forming an electron beam 100 mm in diameter with nonuniformity of the current density distribution not exceeding  $\pm 6\%$ . In addition to the hollow cathode and the reflector cathode, both made of magnetic steel, it includes a permanent magnet, a copper anode, and expander with the discharge chamber, a perforated steel-disk accelerating electrode and a perforated steel-disk emitter electrode, the latter replaceable by a steel-mesh emitter electrode without accelerating electrode, also a redistributing electrode and insulators where required. Helium is the working gas fed into the hollow cathode at a rate not exceeding  $350 \text{ cm}^3 \cdot \text{atm/h}$ , but argon or air can be used instead. The gun operates in three modes: (1) at gas pressure  $\sim 10^{-2} \text{ Pa}$  and expander potential not higher than plasma potential ( $+300 \text{ V}$  relative to cathodes) at the hole in the reflector cathode,  $\alpha = I_b/I_d \leq 0.2$  ( $I_b$ -beam current,  $I_d$ - discharge current), (2) gas pressure  $\sim 10^{-2} \text{ Pa}$  and high expander potential,  $\alpha = 0.4$  with controllability of current density distribution over beam cross section through regulation of electron flux in expander, (3) gas pressure  $\geq 5 \cdot 10^{-2} \text{ Pa}$  with discharge between expander and cathodes,  $\alpha = 0.8$  and gun efficiency up to 91%. In mode (2) the gun efficiency reaches 87% with accelerating and emitter electrodes or 94% with steel-mesh emitter electrode alone. The gun current can be regulated over the 0-0.5 A range through regulation of anode and expander potentials.

Figures 3, references 5: 2 Russian, 3 Western.

[21-2415]

## TIME-OF-FLIGHT SYSTEM WITH AUTOMATIC CONTROL AND LOGICAL DATA SAMPLING FOR 'NATALIYA-2' GAMMA-TELESCOPE

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
 (manuscript received 29 Jun 81) pp 45-49

AKIMOV, D. Yu., BELENKO, S. Ye., KOTOV, Yu. D., ROMANOV, O. N. and SAMOYLENKO, V. T., Moscow Institute of Engineering Physics

[Abstract] The time-of-flight system for the "Nataliya-2" gamma-telescope includes automatic control that compensates for the time instability of electronic channels so as to maintain a constant signal propagation time through them. It replaces the conventional Cerenkov counter, its advantages

being much lower background noise produced by particles moving in opposite direction and lower threshold energy of recordable  $\gamma$ -quanta. The instrument consists of two scintillation counters (polystyrene with addition of n-terphenyl and POPOP), each scanned from two opposite faces by sets of three photomultipliers through stripline optical waveguides. Each set of photomultipliers feeds into one of four electronic channels consisting of an events sampler with logic, an amplifier, a D-trigger prioritization-type discriminator of precise intermittent locking, a delay line with 0.1 ns adjustment steps, a reversible counter, and an intermittent comparator. The instrument includes also a tuning oscillator. Application of a voltage to the oscillator control busbar cuts the oscillator off and switches operation of the instrument from "tune" mode to "measure" mode. The instrument has been designed for stable operation over the 0-40°C temperature range and during  $\pm 10\%$  fluctuations of the supply voltage. The authors thank Yu. K. Akimov and V. A. Kaplin for constructive discussions and interest in the project, also S. L. Smirnova for building the scintillator. Figures 2, references 16: 12 Russian, 4 Western.

[21-2415]

UDC 539.1.074.83

#### COMPLEX SYSTEMS FOR REGISTRATION OF NEUTRONS

Moscow PRIORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
(manuscript received 25 Jun 81) pp 39-42

KOZLOV, I. M., NIKOTIN, O. P. and CHEKRENEV, A. S., Leningrad Institute of Technology

[Abstract] A system for registering thermal neutrons has been developed that consists of many proportional counters, each a tube filled with  $\text{He}^3$  and with its individual circuit consisting of amplifier, discriminator and signal shaper. The system features high resolution, ensures easy inspection and alignment, provides for summation of signals in many different combinations through OR logic, offers a wide choice of switching modes and the possibility of automatic control through NAND logic. High interference immunity has been achieved by double shielding of the most vulnerable units, operation is facilitated by having the entire array of counters subdivided into groups with separate power supplies and controls with filtering and regulation. All connections are soldered, ensuring high reliability with infrequent disassemblies. One version of this system, consisting of 12 SNM-18 counters in a 47 x 32 x 32 cm vat with paraffin as moderator, has been built for registering delayed neutrons generated by photofission of heavy nuclei. A near- $4\pi$  registration geometry is feasible with 4 groups of 3 counters. Better separation of neutron signals from  $\gamma$ -radiation photons is possible with up to 30 counters in the system. Figures 2, references 4: 2 Russian, 2 Western.

[21-2415]

UDC 621.384.61

STABILIZATION OF LONGITUDINAL FLUCTUATIONS IN HEAVY-ION STORAGE RINGS

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
(manuscript received 5 Feb 81) pp 36-39

ZENKEVICH, P. R. and KOSHKAREV, D. G.

[Abstract] A method of stabilizing the longitudinal coherent dissipative fluctuations in heavy-ion storage rings for thermonuclear fusion is proposed, namely ensuring an appropriate momentum distribution of particles through matching of the system parameters. The technique is based on the dispersion equation for an unbunched ion beam, which yields a stability criterion with much more current flexibility than stabilization according to the Keil-Schnell criterion. This is demonstrated by hodographs of the  $J_D^{-1}$  sign  $\gamma$  vector ( $J_D$  - dispersion integral,  $\gamma = -d(\log \Omega)/d(\log p)$ ,  $\Omega, p$  rotational speed and momentum of particles in the ring) for a parabolic momentum distribution without tail and for momentum distributions with  $x = \frac{(\Delta p/p)}{(\Delta p/p)_0} = 1, 2, 4, 8$  tails,

which extend the upper limit on the quiescent current from 1.2 A (Keil-Schnell criterion) correspondingly to 2.7-170 A with a proper form factor. Figures 4, table 1, references 5: 1 Russian, 4 Western.

[21-2415]

UDC 621.383

CONVERSION OF OPTICAL IMAGES BY TIME-PULSE METHOD WITH AID OF SEMICONDUCTOR PHOTORESISTORS

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
(manuscript received 7 Jul 81) pp 206-207

BONDAREV, G. S., All-Union Scientific Research Institute of Synthetic Resins, Vladimir

[Abstract] The feasibility of using semiconductor photoresistors for conversion of optical images by the time-pulse method is problematic, because of the inherent lag between illuminance input signal and photocurrent output signal. At a certain ratio of light photocurrent to dark photocurrent. However, the rise time and the fall time of a photocurrent pulse become equal, with the corresponding optimum photoreistor load resistance decreasing as the illuminance increases. This property of semiconductor photoresistors makes them suitable for image conversion when the input pulses are symmetric in shape and are spaced widely enough. A converter has been built on this basis with two SF3-1 photoresistors, one loading the other and compensating load errors through automatic correction, connected into a bridge circuit with a bank of three resistors and a reference-frequency oscillator as pulsed

voltage supply ensuring minimum error due to illuminance fluctuations. The device operates stably when supplied with rectangular voltage pulses at repetition rates up to 0.5 MHz and duty factor ranging from 0.05 to 0.5. Figure 1, references 2 Russian.

[21-2415]

UDC 681.3

#### SYSTEM FOR AUTOMATICALLY SYNCHRONIZING MODULATORS OF SILUND ACCELERATOR

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 4 Jan 81) pp 20-23

DUBOVIK, L. V., INKIN, V. D., NIKOLAYEV, V. P., SAYENKO, T. P. and  
SMIRNOV, A. V., Joint Institute of Nuclear Research, Dubna

[Abstract] The accelerating field in the SILUND induction linac is set up by a system of pulsed inductor-transformers excited by nanosecond square pulses. The pulse generators (modulators) are made up of lumped capacitances, a hydrogen thyratron and a shaping line. A total of thirty modulators is used. Time synchronism of modulator operation is important for the quality of acceleration. There are two types of instabilities when hydrogen thyratrons are used in the pulse generators: fast ignition instability, i.e. variation in the time of thyratron firing from pulse to pulse, and a slow gradual change of ignition time over a long period. Fast instability can be reduced to 2 ns by individual matching of working conditions of the hydrogen generators. In this paper the authors examine a synchronization system for eliminating slow instability of thyratron firing, an automatic control system on-line with the TRA-1001/i computer. The actuating and measurement parts of the system are made in the CAMAC standard and are located about 100 m from the computer. Coupling to the computer is through a CAMAC extension branch. A block of delay lines synchronizes the firing times of the 30 modulators. Figures 6, references 11 Russian.

[20-6610]

UDC 539.171

#### SPIN-FLIPPER WITH MAGNETIC FIELD CORRECTION

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 27 Apr 81) pp 24-25

MOSTOVY, Yu. A.

[Abstract] A disadvantage of devices using current-carrying foil to switch mutual directions of the driving magnetic field and polarization vector of the neutron beam is the loss of polarization in the off-axis part of the beam.

This is because the finite width of the foil gives rise to a magnetic field component directed perpendicular to the plane of the foil with amplitude depending on the distance to the axis of symmetry. Formulas are derived for estimating the resultant loss in polarization, and a simple method is proposed for correcting the foil in a spin-flop device for a beam of polarized neutrons. In the proposed technique, compensating currents are set up at the edge of the foil that produce magnetic field components perpendicular to the plane of the foil and directed in the opposite direction to the field due to the finite width of the foil. Such currents can produce an effect equivalent to increasing the width of the foil by a factor of 64. Reference 1 Russian. [20-6610]

UDC 621.316 ÷ 621.378

#### DEVICE FOR POWER SUPPLY TO GAS-DISCHARGE ION SOURCE

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 31 Jul 81) pp 146-150

BRYUKHANOV, A. N., LATUSHKIN, S. T. and YUDIN, L. I.

[Abstract] Parameters of ion beams generated in accelerators are especially sensitive to stability of the voltage or current of the arc discharge. In addition, generation of multiply charged ions requires maintaining a voltage across the arc discharge of 300-500 V at 20 A or more. Powerful vacuum-tube circuits are generally used in the stabilization circuits as transistors cannot generally handle the necessary range of voltages and currents. The authors have developed a power supply in which the power dissipated by the regulating transfer transistors in the pulsed and continuous modes is reduced by using two stabilizing circuits. The first (fast) circuit controls the discharge mode, and includes power transistors in the output stage. The second (slow) circuit holds the voltage constant across the regulating transistors of the first circuit as the voltage varies across the load in a wide range. The device can handle up to 15 A in the continuous mode, and up to 40 A in the pulsed mode for pulse duration of 10 ms and duty factor of 0.1 or less. Voltage across the load may reach 500 V. The device has a speed of about 10  $\mu$ s and coefficient of stabilization of about 1000 relative to current or voltage. Figures 4, references 9 Russian.  
[20-6610]

DEVICE FOR IDENTIFYING PARTICLES BY PHOTOMULTIPLIER PULSE SHAPE

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 17 Mar 81) pp 157-159

SHCHADIN, N. N.

[Abstract] Devices for particle identification based on comparing charges of scintillation signal components from a photomultiplier have a fairly low level of registration and are operationally simple and reliable. Their disadvantages are comparatively low count rate limited by the time constant in the total charge integration circuit, and nonlinearity in the low-energy region due to the presence of a diode in the integration circuit of the fast component. A device is proposed that partly eliminates these disadvantages by using active restoration of integrating capacitances and preliminary biasing of the diode in the integrating circuit of the fast component. The unit is made up of a total charge integrator, a fast component integrator, a comparison circuit and a control circuit. The operating cycle is broken down into two stages: integration of the total charge and fast component (0.5-0.6  $\mu$ s), and generation of output controlling pulses corresponding to the result of comparison with immediate restoration of voltages across the integrating capacitors (0.4-0.5  $\mu$ s). Gamma pulses are suppressed by a factor of about 200 at a neutron registration threshold of 0.25 MeV with countrrate of about 9 kHz. Figures 3, reference 1 Russian.

[20-6610]

LASER NANOSECOND PULSE GENERATOR FOR PLASMA DIAGNOSIS

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 8 Jun 81) pp 170-172

VIKHAREV, V. D., DOROKHIN, L. A., TULUPOV, M. V. and TSARFIN, V. Ya.

[Abstract] The paper describes the Luch-2 laser system designed for diagnosing processes that take place when the energy of a relativistic electron beam generator is concentrated on a target. In contrast to conventional systems for forming a short laser pulse, the Luch-2 does not require an additional external electro-optical shutter. The working principle is based on time modulation of polarization of a giant pulse inside the cavity of the master laser. A three-electrode spark discharger is used for positive synchronization of the laser emission and the process being studied. Operating time is 115 ns. Laser pulses of 3 ns duration can be generated. Figures 2, references 3 Russian.

[20-6610]

UDC 538.6.078.2

FACILITY FOR SYNCHRONIZING MONOPULSE RUBY LASER WHEN STUDYING SHOCK WAVES  
IN TUBES

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 11 Mar 81) pp 172-174

MEDVEDEV, V. M. and SHEVTSOV, V. D., Leningrad State University

[Abstract] When monopulse lasers are used as the light source in shock wave experiments, the lamps in the pumping circuit must be ignited before the shock wave reaches the investigated section of the tube, with a lead time equal to that required for pumping the active substance of the laser. However, the shock wave velocity is not the same, varying from one experiment to the next. The authors describe a facility that uses piezoelectric shock wave indicators and a simple synchronizer made up of a slave square-pulse generator, integrator and comparator. When the shock wave operates the first indicator, the square-wave generator produces a pulse resulting in a linearly increasing voltage at the output of the integrator. This voltage rises until the shock wave reaches the second indicator, resetting the square wave generator and causing the voltage to begin falling. Resistors in the circuit synchronize the time when the voltage reaches its initial value with the instant of arrival of the shock wave at the investigated section. This facility minimizes the distance of the shock wave from the investigated section at the instant of laser operation to  $\pm 2$  mm for shock wave velocities 350-1000 m/s. Figures 3, references 3 Russian.

[20-6610]

UDC 621.375.826

STABLE GAS-DISCHARGE WATER-VAPOR LASER WITH GENERATION OF ORTHOGONAL  
POLARIZATIONS

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 15 Apr 81) pp 174-179

ZAV'YALOV, V. V. and BOGOMOLOV, G. D., Institute of Physics Problems,  
USSR Academy of Sciences, Moscow

[Abstract] The paper describes a gas-discharge laser that operates on mixtures of  $H_2 + H_2O$  or  $D_2 + D_2O$ . The discharge tube is fused quartz, 320 cm long and 75 mm in outside diameter with walls 3 mm thick. A tube 90 mm in diameter was used for wavelengths of 172 and 220  $\mu m$ . The discharge tube is suspended on rubber rings inside a thick-walled glass tube. Cooling is by water flowing in the space between the quartz and glass tubes. The laser cavity is formed by a flat mirror and a spherical mirror with radius of curvature of 700 cm. The distance between mirrors was varied from 320 to 380 cm in various experiments. The design provides the capability of

simultaneous lasing output with orthogonal linear polarizations with difference frequency from a few kHz to tens of MHz. This effect is produced by adjustable anisotropy of the laser cavity. The two-frequency mode of laser operation is especially convenient for use in heterodyne arrangements, and in particular for plasma-diagnosis interferometers when converting amplitude and phase information about an exposed object from the optical range to radio frequencies. Figures 2, table 1, references 9: 7 Russian, 2 Western.  
[20-6610]

UDC 621.373.018.756:621.373.029.67

#### STABILIZING ACTIVE MODE LOCKING IN ARGON LASER

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 19 Jan 81) pp 179-181

VASIL'YEV, I. I., KUZ'MIN, V. V., LIVSHITS, M. G. and SASUNKEVICH, V. A.,  
Belorussian State University, Minsk

[Abstract] An argon laser is described with intracavity electro-optic modulation of radiation and automatic frequency adjustment of internal perturbations for stabilizing amplitude and phase characteristics of laser pulses. The intracavity electro-optic modulator (DKDP crystal, longitudinal geometry) was installed in a laser cavity 1.7 m long. The modulator was excited by an oscillator on the intermode beat frequency of about 80 MHz. The cavity was optimized for lasing on the  $TEM_{00}$  mode. A quartz autocollimation prism was used for tuning wavelengths, and low-frequency pulsations in the power supply were smoothed by an LC-filter. Pulsations of output emission on 300 Hz did not exceed 1% at discharge currents up to 25 A. Output power was 200 and 180 mW for wavelengths of 0.48 and 0.51  $\mu$ m respectively. Voltage amplitude across the modulator is 800 V at supply voltage of 60 V. The proposed modulator provides active mode locking of 30-40 longitudinal modes (output pulse duration of about 200 ns). The automatic tuning system ensures phase stability of optical pulses within limits of  $\pm 5$  ns for ten hours of continuous operation under laboratory conditions. Figures 3, references 3: 2 Russian, 1 Western.  
[20-6610]

80-kOe SUPERCONDUCTIVE SOLENOID OPERATING IN UNDAMPED CURRENT MODE

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 29 Jul 81) pp 184-186

KOSHURNIKOV, Ye. K., NIZHANKOVSKIY, V. I., NIKOLAYEV, Ye. G.,  
PYLININA, S. N. and SHAKHTARIN, V. N., Institute of Physics Problems,  
USSR Academy of Sciences

[Abstract] A short-circuited solenoid with improved homogeneity is described that is made from superconductive cable (multistrand wire) and gives a field of up to 80 kOe (6.37 MA/m). The coil was wound on a brass form with mylar insulation between layers. Inside radius 24.9 mm, outside radius 59.0 mm, length 249.8 mm, radius of outer recess 52.2 mm, length of recess 162 mm, diameter of free aperture 42 mm. The superconductive cable was grade KEVTA-2NT 0.7 mm in diameter insulated with viniflex lacquer. Inductance of the solenoid 2.82 H. Number of turns 12778, critical current 136 A, maximum field in center of solenoid 79.4 kOe (6.318 MA/m). Inhomogeneity of the field along the axis due to deviations of actual dimensions from the assigned values is of the order of  $10^{-5}$  or less per 10 mm. Decay of the field as measured by the NMR method is  $10^{-5} \text{ h}^{-1}$ . Total resistance of all normal (non-superconductive) sections of the solenoid is 8 nΩ. Figure 1, references 6; 4 Russian, 2 Western.

[20-6610]

FACILITY FOR PRODUCING HIGH PRESSURES AND PULSED MAGNETIC FIELDS

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 23 Sep 80) pp 186-187

GOVOR, G. A., DOBRYANSKIY, V. M. and MAKOVETSKIY, G. I., Institute of Solid State Physics and Semiconductors, BSSR Academy of Sciences, Minsk

[Abstract] A facility is described for studying magnetic properties of materials under the action of pressure up to 12 kbar in gas atmosphere, and a pulsed magnetic field of up to 24 MA/m in the temperature range from 4.2 to 400 K. The high-pressure generator consists of a hydraulic diaphragm compressor, a booster, and a system of hydraulic valves. Initial pressure is 100-150 atmospheres, the gas pressure in the tank. The diaphragm compressor raises the pressure in the system to 2 kbar, and the booster produces a further increase to 12 kbar. The pulsed magnetic field is set up by a solenoid with a working gap of 6 mm with flip coil and compensating coil for measuring the magnetization of specimens. The chamber includes a cryostat for temperature studies. The solenoid is energized by a capacitor bank with capacitance of 1 mF. This facility has been used to plot the PTH diagram of magnetic transformations in manganese arsenide. Figures 2, references 4: 3 Russian, 1 Western.

[20-6610]

VACUUM X-RAY DIODE

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 6 Oct 81) pp 188-189

GANEV, A. S., ZAPYSOV, A. L., IZRAILEV, I. M., NIKITIN, V. P.,  
PODGORNOV, V. A. and KHAVRONIN, N. A.

[Abstract] A vacuum x-ray diode is described for measuring the time dependence and total energy of x-radiation of the laser plasma produced in laser-driven implosion of microspheres on a multibeam neodymium laser fusion facility. The supply cable carries a voltage of +1.5 kV, and the output cable is a 6-meter length of RK75-9-13 that goes directly to an SRG-5 oscilloscope. The photocathode is 10 mm in diameter, and the anode is a grid located 1 mm away from the photocathode with transmission of 0.7. Wave impedance of the diode is 75 ohms. Supply is from a ring capacitor in direct proximity to the anode grid. Spacing between detector and target can be changed without breaking the vacuum in the working volume of the chamber. Electric signal reflections are prevented by making the transmission channel in the form of a conical line matched to the cable. Time resolution is 200±50 ps. The diode has constant sensitivity over a quantum energy range of 0.08-1.7 keV:  $1.8 \cdot 10^{-20}$  C/keV with accuracy of ±20%. Figures 2, references 5: 2 Russian, 3 Western. [20-6610]

SPACE CHARGE MEASUREMENT IN DIELECTRICS EXPOSED TO PULSED ELECTRON BEAM

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 27 Jan 81) pp 194-196

SOLOV'YEV, Yu. A. and YAGUSHKIN, N. I., Scientific Research Institute of Electronic Internal Flaw Detection at Tomsk Polytechnical Institute

[Abstract] The paper proposes a technique and device for measuring space charge in the process of pulse irradiation. The source of radiation was a betatron with extracted electron beam operating at a frequency of 50 Hz. The time interval between betatron emission pulses is about 15 ms, which is much greater than the cycle of acceleration and extraction of electrons. A space charge accumulates in a dielectric exposed to the electron beam from the betatron. A source of beta particles is installed on the surface of the specimen on the side of the incident radiation. Electrons transmitted through the specimen are recorded by a scintillation detector. Pulses from the detector go to the inverting input of an opamp. A voltage equal to the discrimination level is applied to the noninverting input. The opamp output signal goes to a pulse shaper that sends a signal with amplitude of 2.5 V and

duration of 12  $\mu$ s to a coincidence gate. The recording channel is controlled by a square pulse generator with delay. The output from the generator goes to the coincidence gate, enabling transmission of pulses from the detector due to the beta source, which are registered by a scaler and printed out. The recording channel is disabled during the accelerator radiation cycle by the absence of an enabling pulse on the input of the coincidence gate. Curves are given showing the space charge density in polymethyl methacrylate as a function of exposure time at a charge injection rate of  $0.8 \cdot 10^{-3}$  A/m<sup>3</sup> and temperatures of 300 and 226 K. Figures 2, references 4 Russian.  
[20-6610]

UDC 621.378.34

#### LZhI-503 TUNABLE PULSED DYE LASER

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 3, May-Jun 82  
(manuscript received 18 Mar 81) pp 249-250

DYATLOV, M. K., KURBATOV, A. V. and ORESHAK, O. N.

[Abstract] The LZhI-503 tunable dye laser emits in the visible region and is a convenient tool for research in atmospheric studies, analyzing the composition of various media, plasma diagnosis and the like, as well as for a variety of metrological applications. It can also be used for improving resolution of holograms, photochemical separation of isotopes and control of chemical reactions. The facility includes a nitrogen laser for stimulating emission of the dye, a tunable laser as the output emitter, and a set of various dyes as active elements. Emission frequency is changed by using rapidly interchangeable cells. The operation takes a few seconds and does not involve realignment. Output frequency can also be continuously tuned manually or automatically over selected ranges. Versatility of the LZhI-503 is due to the bandwidth of pulsed emissions, covering the entire visible spectrum from 360 to 700 nm, and also to simplicity of tuning. Width of the lasing line is 0.05 nm or less, maximum pulse power is 25 kW, pulse duration is 5 ns or less, pulse recurrence rate is 1-100 Hz, and average service life is 2000 hours or longer. Emitter dimensions 485 x 355 x 260 mm, mass 25 kg. Estimated price is 10,000 rubles.  
[20-6610]

FLUID MECHANICS

UDC 539.3:534.1

DIFFRACTION OF ELASTIC WAVES BY ROUGH BODIES

Tashkent IZVESTIYA AKADEMII NAUK UzSSR: SERIYA TEKHNICHESKIKH NAUK  
in Russian No 3, May-Jun 82 (manuscript received 27 Jan 82) pp 31-34

ISRAILOV, M. Sh., Moscow Institute of Structural Engineering  
imeni V. V. Kuybyshev

[Abstract] Diffraction of SH waves at the boundary between an isotropic elastic medium and a rough half-plane wedge is considered, taking into account sliding of the wedge and friction at its surface. The corresponding wave equation is solved in elliptic regions (diffraction circles) and hyperbolic regions around the edge, first for a step wave and then for an arbitrary plane wave using the Duhamel integral, also for a wave with circular front. This diffraction problem for longitudinal SV waves is solved by the method of successive approximations in elliptic and hyperbolic regions around the edge, the zeroth approximation for elliptic regions (diffraction circles) being established by the method of functionally invariant solutions.  
Figure 1, references 6: 5 Russian, 1 Western.  
[13-2415]

UDC 533.6.001.2

DRAG OF SOLID OF REVOLUTION WITH CENTRAL CHANNEL IN SUPERSONIC FLOW

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 42, No 3, Mar 82  
(manuscript received 14 Jun 81) pp 405-408

TSYMBALOV, V. V.

[Abstract] A numerical study was made of supersonic flow around a solid of revolution with a central channel, to determine the effect of changes in shock-wave structure due to changes of stream velocity along the path. Cylinders with length(L)-to-diameter(D) ratios of 1.5 and 2.25 were tested, each having a central channel with diameter  $d \leq 0.9D$  chamfered at the

entrance ( $2^\circ$ ,  $20^\circ$ ,  $90^\circ$ ) and at the exit ( $20^\circ$ ,  $26^\circ$ ,  $90^\circ$ ). With all combinations of chamfer angles, except the  $90^\circ$ - $90^\circ$  combination corresponding to no chamfer and flat edge at both ends, the edge at the entrance was either left sharp or made blunt. The velocity of the stream without perturbation was varied over the  $1.2 \leq M_\infty \leq 6$  Mach range. Calculations were made according to a non-steady difference scheme based on nonrectangular grid cells for the system of Euler equations in a cylindrical system of coordinates, with standard boundary conditions at infinity and at solid surfaces, also on the axis of symmetry. The results reveal how the drag coefficient depends on blunting of the entrance edge, on the relative channel diameter, and on the channel chamfer angle, also that the flow stabilization time increases fast with decreasing  $d/D$  ratio. Without oscillations due to a whirlpool at the front end, machine time on a BESM-6 computer for a grid with 2500-3000 nodes did not exceed 3 hours. Figures 3, references 3 Russian.

[12-2415]

UDC 536.2

TRANSIENT TEMPERATURE FIELD OF CLOSED THIN INFINITELY LONG CIRCULAR  
CYLINDRICAL SHELL SINKING INTO FLUID

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 43, No 2, Aug 82  
(manuscript received 19 Jun 81) pp 333-334

LITVINOVA, A. F.

[Abstract] The transient temperature field is calculated for a closed thin cylindrical shell as the latter, its initial temperature equal to temperature of ambient air, sinks into a fluid at some other initial temperature flowing at some constant velocity. Calculations are based on the equation of heat conduction for thin shells in a moving system of coordinates, with the temperature a function of heat transfer coefficient and of time. They involve Laplace and inverse Laplace transformations by the Obraztsov-Onanov method. Figure 1.

[11-2415]

## COMPRESSION OF SPHERICAL TARGETS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 3, May-Jun 82 (manuscript received 13 Oct 80) pp 120-126

SVALOV, A. M., Moscow

[Abstract] Compression of spherical fluid bodies by an isentropic or non-isentropic process, leading to an infinite value of the integral  $\int_0^R \rho dr$  ( $\rho$ - density of fluid,  $R$ - radius of sphere) in the final stage, is analyzed on the basis of self-adjoint solutions to the problem. Calculations involve the equation of state and the equations of motion for compressible fluids. The thermodynamic functions are calculated by methods of dimensional analysis and similarity. The resulting differential equations are solved accordingly and values of exponents are established that satisfy the condition of finite mass and total energy with divergent integral defining  $\int_0^R \rho dr$  for a sphere of any finite radius corresponding to any instant during the compression process. The results are examined in planes of parameter pairs that reveal the asymptotic behavior of the solutions as well as the boundaries of regions where such solutions exist and the boundaries between various modes including that of a shock wave. Figure 1, references 9: 7 Russian, 2 Western. [9-2415]

## SUPERSONIC FLOW OF DUSTY GAS PAST BLUNT BODY

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 3, May-Jun 82 (manuscript received 1 Sep 80) pp 73-77

GOLOVACHEV, Yu. P. and SCHMIDT, A. A., Leningrad

[Abstract] Supersonic flow of dusty gas past a blunt body is analyzed in accordance with the theory of embedded continua, using as parameters the "fictitious" densities of both gaseous and solid phases and the volume fraction of solid particles. The latter are assumed to be spherical, all having the same diameter, and their concentration to be sufficiently low to make any direct interaction between them negligible. The concentration of free electric charge carriers is assumed to be sufficiently low to make interphase mass and charge transfer negligible. Brownian motion is also disregarded so that the only forces acting in the two-phase medium are those of buoyancy and gas pressure. Heat conduction through solid particles is disregarded, inasmuch as the time of thermal relaxation inside such a particle is much shorter than the characteristic time of two-phase flow. Viscosity and thermal

conductivity of the gas are included in analysis of gas-dust interaction. Calculations are based on the fundamental equations of mass, momentum, and energy conservation for a two-velocity two-temperature continuum. To these equations is added the equation of state for a perfect gas. The system of equations must be supplemented with relations  $C_d = f(Re, M, Kn, Pr, \dots)$  and  $Nu = f(Re, M, Kn, Pr, \dots)$  ( $C_d$ - drag coefficient,  $Nu$ - Nusselt number,  $Re$ - Reynolds number,  $M$ - mach number,  $Kn$ - Knudsen number,  $Pr$ - Prandtl number) obtainable from experimental data. Numerical results have been obtained for a body with spherical tip having a radius of 0.43 m in a supersonic air stream flowing at Mach  $M_\infty = 1.5$  and containing dust particles  $d = 5 \cdot 10^{-6}$  m in diameter of a material with density  $\rho = 3.7 \cdot 10^3$  kg/m<sup>3</sup> and specific heat  $c = 1.25 \cdot 10^3$  J/(kg·K). The shock wave has been accounted for according to Rankine-Hugoniot relations. Figures 5, references 10: 8 Russian, 2 Western.  
[9-2415]

UDC 532.526.5

#### SEPARATION FLOW OF IDEAL FLUID PAST WING WITH INFINITE ASPECT RATIO AND FLAP

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 3, May-Jun 82 (manuscript received 1 Sep 80) pp 65-72

ZUBTSOV, A. V. and SUDAKOV, G. G., Moscow

[Abstract] The authors consider an aircraft wing in the form of a flat rectangular plate with infinite aspect ratio and a triangular flap with a small vertex angle moving through a steady stream of ideal fluid at a low angle of attack. In order to determine the flow pattern, with separation it is necessary to determine the potential that will satisfy the three-dimensional Laplace equation for boundary conditions of impermeability at wing and flap surfaces, boundary conditions of zero pressure jump and zero jump of normal velocity at the vortex sheet, and the Chaplygin-Zhukovskiy condition along the trailing edge of wing and the lateral edges of the flap. The problem is formulated for four distinct regions, two with two-dimensional flow and two with three-dimensional flow. It is solved by the method of asymptotic expansions for each region and subsequent collocation at their boundaries. An algorithm of numerical solution on this basis has been constructed, and results are shown for a typical flap with 20° vertex angle and a wing moving at a 5° angle of attack. The solution is found to be self-adjoint at the boundary between regions of two-dimensional and three-dimensional flow, with full circulation in the vortex sheet. Rarefaction peaks increase behind the wing-flap contact line. The authors thank G. P. Svishchev for formulating the problem and taking interest in the study. Figures 4, references 6: 5 Russian, 1 Western.  
[9-2415]

THREE-DIMENSIONAL BOUNDARY LAYER AT BLUNT BODIES WITH PERMEABLE SURFACE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA  
in Russian No 3, May-Jun 82 (manuscript 3 Dec 80) pp 49-58

BRYKINA, I. G., GERSHBEYN, E. A. and PEYGIN, S. V., Moscow

[Abstract] Flow in a three-dimensional boundary layer at a blunt body in a supersonic stream of compressible gas is analyzed on the basis of corresponding partial differential equations in a nondegenerate system of curvilinear coordinates with origin at the stagnation point, with the metrics of the body space  $R^3$  expressed in terms of covariant components of the basis metric tensor. Body surfaces with a pressure gradient of the order of  $0(p_\infty V_\infty^2/R)$  are considered ( $p_\infty, V_\infty$  - density and velocity of gas in oncoming stream far from body), for which these equations have been validated by asymptotic analysis of Navier-Stokes equations for supersonic flow around blunt bodies with injection. These equations are solved analytically by the method of successive approximations and numerically by the method of finite differences. Analytical expressions in the first approximation for velocity components, enthalpy, friction coefficient and heat transfer coefficient are derived from the zeroth approximation in the form of an exponential function or the integral of an exponential function, asymptotic expressions being then obtained for components of frictional pressure and thermal flux in the extreme case of very low injection or suction angle. A comparison is made between analytical and numerical results for an impermeable surface, for an ideal catalytically active surface in a stream of dissociated and ionized gas, and for a permeable surface with laminar boundary layer. The agreement is satisfactory for a boundary layer with strong injection. Figures 5, references 13; 12 Russian, 1 Western.

[9-2415]

SOME FEATURES OF HEAT TRANSFER AT SURFACE OF BODY NEAR CYLINDRICAL BARRIER  
AND TRANSVERSE JET

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 3, May-Jun 82 (manuscript received 8 Aug 80) pp 41-48

BOROVY, V. Ya., PLESHAKOVA, L. A. and RYZHKOVA, M. V., Moscow

[Abstract] An experimental study was made of turbulent heat transfer at a slightly blunted cone with a  $5^\circ$  vertex angle across a jet with a Mach number  $M = 6.1$  inside a shock tube constituting a cylindrical barrier. The Reynolds number, referred to stream parameters at the outer edge of the boundary layer and distance from cone tip to cylinder axis, was varied from

$16 \cdot 10^6$  to  $84 \cdot 10^6$  through corresponding variation of total pressure. Two series of measurements were made to determine the dependence of thermal flux and heat transfer coefficient on the relative jet temperature, the surface temperature of the cone, and the stagnation temperature in the stream core. Raising the jet temperature at a constant surface temperature was found to intensify the heat transfer before the nozzle with the heat transfer coefficient increasing linearly, while the thermal flux near the shock wave behind the nozzle was found not to depend on the temperature of the injected gas. The results agree with those of theoretical analysis. Figures 6, references 15: 14 Russian, 1 Western.

[9-2415]

UDC 533.6.011.8

#### GASDYNAMIC PARAMETERS IN VICINITY OF BODIES IN STREAM OF FREE MOLECULES

Moscow IZVESTIYA AKADEMII NAUK SSSR; MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 24 Oct 80) pp 177-180

BASS, V. P. and BRAZINSKIY, V. I., Dnepropetrovsk

[Abstract] A stream of free molecules of rarefied gas is considered flowing around a stationary arbitrarily convex body in absence of external forces. The quiescent flow is at equilibrium, with Maxwellian distribution of molecules with respect to velocity. The body surface is impermeable and non-radiating, its interaction with the gas being a hybrid specular-diffuse one. Expressions are obtained for the radial profiles of concentration, velocity and temperature. These expressions contain volume integrals of intricate functions that are difficult to evaluate in closed form, unless they are replaced with surface integrals. Some macroparameters have been evaluated by this method for bodies of simple shapes, one consisting of conical segments and one consisting of a cylindrical segment with spherical bases. Isolines of mean free paths have been plotted for incident particles in the reflected stream and for reflected particles in the incident stream. The results are applicable to estimation of gasdynamic parameters around the "Kosmos-196" satellite at altitudes higher than 150 km above ground in an atmosphere describable by the CIRA-1965 model. Figures 2, references 5: 4 Russian, 1 Western.

[8-2415]

## DEPENDENCE OF LAMINAR-TO-TURBULENT BOUNDARY LAYER TRANSITION ON ANGLE OF ATTACK OF POINTED CIRCULAR CONES IN SUPERSONIC STREAM

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 4, Jul-Aug 82 (manuscript received 20 Nov 80) pp 160-163

YUSHIN, A. Ya., Moscow

[Abstract] An experimental study was made of transition from laminar to turbulent boundary layer in plane of symmetry of a cone in a supersonic stream. Measurements were made inside a shock tube, with the stream flowing at  $M = 6.1$  around a 300 mm long circular cone with a  $20^\circ$  vertex angle and a blunting radius at the tip not larger than 0.1 mm. According to measurements of surface roughness with a profilometer, the height of asperities was two orders of magnitude smaller than the thickness of the boundary layer during transition. The temperature factor, ratio of surface temperature to stagnation temperature, was 0.51 at a stagnation temperature of 570 K and a total pressure of 7.7 MPa. Temperatures were measured with microthermocouples, thermal flux was measured with a nichrome-foil calorimeter. The data have been evaluated in terms of dependence of the Stanton number on the Reynolds number and of the Reynolds number on the angle of attack  $\alpha$ , over the  $+(0-10^\circ)$  range of the latter. Transition from laminar to turbulent boundary layer is indicated by a sharp change of trend of the curves fitting the test points and approximating those relations. The data have also been evaluated in terms of a theoretical relation between transverse flow spreading and angle of attack, with vertex angle of the cone and ratio of gas densities before and behind the density jump as parameters. The results reveal that the ratio of  $Re_t M_e^{-3})_\alpha \neq 0 / (Re_t M_e^{-3})_\alpha = 0$  ( $Re_t$  - Reynolds number at beginning of transition,  $M_e$  - Mach number at outer edge of boundary layer) is a function of one parameter only, namely a parameter characterizing the effect of a gradient of transverse spreading velocity. Figures 3, references 11: 6 Russian, 5 Western.

[8-2415]

UDC 533.69.01

ASYMPTOTIC THEORY OF SEPARATION FLOW AROUND WINGS WITH SMALL ASPECT RATIO

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 4, Jul-Aug 82 (manuscript received 8 Oct 80) pp 141-147

ZAKHAROV, S. B. and SUDAKOV, G. G., Moscow

[Abstract] Steady symmetric separation flow of ideal incompressible fluid around a wing of zero thickness is considered, assuming an aspect ratio  $\lambda = o(1)$  and an angle of attack  $\alpha = O(\lambda)$ . The problem is formulated in a rectangular system of coordinates with origin at the tip of the wing,  $x_1$ -axis along its chord,  $z_1$ -axis along its span, and  $y_1$ -axis orthogonal to both. The flow potential satisfies the Laplace equation with zero boundary conditions at wing surface and vortex sheet. The problem is solved by the method of asymptotic expansions in the potential for seven regions, including region 7 in the wake, region 6 at the trailing edge, and subregions 4,5 of region 3 at the lateral edges, with the Chaplygin-Zhukovskiy condition can be obtained by a method involving three steps: calculating the coefficient in the singular term of the expansion for velocity at the lateral edges corresponding to nonseparation flow and to the three-dimensional problem in linear airfoil theory, determining the configuration and the intensity of the vortex sheet converging from the lateral edges, and outlining the three-dimensional vortex sheet in conformance with the theorem of vortex conservation. The solution applies equally to all regions, with  $o(\lambda^3)$ ,  $O(\lambda^4 \ln \lambda)$ ,  $o(\lambda^{8/3})$ ,  $o(\lambda^{7/3})$ ,  $O(\lambda^4 \ln \lambda)$  errors of potential of potential in regions 1,2,3,4,6 respectively. A typical example demonstrates that this method is much more efficient than the panel method and the methods of discrete vortices. Figures 4, references 14: 4 Russian, 10 Western.

[8-2415]

UDC 533.6.011.8

SLOW FLOW AROUND HOT SPHERE WITH INJECTION AND EVAPORATION AT ITS SURFACE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 4, Jul-Aug 82 (manuscript received 1 Sep 80) pp 128-134

BORIS, A. Yu., Moscow

[Abstract] A spherical particle of material with high thermal conductivity is placed in a slow stream of gas with  $Re_\infty \ll 1$ , its surface uniformly heated or cooled to a temperature  $T_s \neq T_\infty$  during uniform radial injection or suction of gas so that  $Re_s \sim 1$  at the surface. Such a flow is described by the corresponding system of conservation-law equations. These equations, put in dimensionless form with pressure  $p$  replaced by parameter

$$\pi = \left( \frac{p}{p_\infty} - 1 \right) / Kn^2 \text{ and}$$

density  $\rho$  eliminated through the relation  $\rho = T^{-1}$ , are solved for appropriate boundary conditions: velocity  $v \rightarrow Re_{\infty} e_x$  and temperature  $T \rightarrow 1$  at radius  $r \rightarrow \infty$ ,  $v = Re_s e_r$  and  $T = T_s$  at radius  $r = 1$ . The gas is assumed to be monatomic with Maxwellian distribution of molecules, both dynamic viscosity and thermal conductivity proportional to temperature, and  $Pr = 2/3$ . When  $\delta = 0$ , then the Barnett terms  $\delta_{ij} \nabla v$  vanish and the system reduces to Navier-Stokes equations for slow flow. These are solved by the method of asymptotic expansions in small parameter  $Re_{\infty} = \epsilon$  for three regions ( $r \sim 1$ ,  $\rho = \epsilon^{1/2} r \sim 1$ ,  $R = \epsilon^{1/2} \rho = \epsilon r \sim 1$ ) and subsequent collocation. They are solved first for the ideal model with surface temperature independent of injection or suction rate, then for the real case of temperature and injection or suction rate, related through evaporation and condensation of particle material or through absorption and emission of gas at the surface. The solution on the basis of the Navier-Stokes equations is further corrected by inclusion of thermal stresses, which reduce the drag, and addition of Barnett terms ( $\delta_1 = 1$ ). The author thanks O. G. Fridlender for his interest and helpful suggestions. Figures 3, references 10: 8 Russian, 2 Western.

[8-2415]

UDC 533.6.001.72

#### ACTION OF WEAK SHOCK WAVE ON WING WITH COMPLEX PLANFORM AT SUPERSONIC VELOCITIES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 19 Dec 80) pp 121-127

NISHT, M. I., POLOVKOV, A. F. and POPYTALOV, S. A., Moscow

[Abstract] Effects of a weak supersonic shock wave with plane front striking an aircraft in an ideal medium are analyzed, the aircraft moving at constant velocity and zero angle of attack, the shock wave impinging at an arbitrary angle of incidence. The stream parameters behind the wavefront and the wing geometry are given. The action of such a shock wave, characterized by changing the angle of attack and perturbing the pressure field, is calculated on basis of the corresponding wave equation with the Mach number as parameter. This equation is solved for boundary conditions of impermeability at the wing surface, zero pressure drop across the vortex sheet, Chaplygin-Zhukovskiy condition at subsonic rear edges, and continuous transverse pressure gradient except at sites of density jumps. The solution is evaluated with aid of the Cauchy-Lagrange integral and upon introduction of the appropriate unit-step Heaviside function. The final expression for the pressure perturbation in space and time serves as basis for numerical calculation of the transient response of local and integral aerodynamic characteristics of aircraft and wing to arbitrarily oriented weak shock waves. Figures 5, references 6: 5 Russian, 1 Western.

[8-2415]

UDC 533.6.011

STUDY OF FLOW AROUND BLUNT BODIES WITH RADIATIVE HEAT TRANSFER BY METHOD OF LARGE PARTICLES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 1 Dec 80) pp 106-112

BELOTSERKOVSKIY, O. M., DAVYDOV, Yu. M., SKOTNIKOV, V. P. and FOMIN, V. N., Moscow

[Abstract] Hypersonic flow around blunt bodies is analyzed without disregarding radiative energy and pressure. With the system of equations of gas dynamics in Cartesian coordinates split into two auxiliary ones, one for the Euler stage (splitting parameter  $\delta = 1$ ) and one for the Lagrange and final stages (splitting parameter  $\delta = 0$ ), radiative heat transfer is included in two ways: approximation of bulk glow and approximation of plane layer. The problem is solved by the method of large particles, with use of a uniform finite-difference ( $\Delta x, \Delta y, \Delta t$ ) grid for evaluation of the total energy. Calculations have been made for a sphere, a flat shoulder, and a cylindrical stub in a stream of dissociated and ionized radiating air at Mach  $M = 33-42$ , at an altitude  $H = 40$  km above the earth. Numerical data pertaining to temperature, density, velocity, radiant flux profiles and their dependence on body geometry have been obtained in both approximations. A comparison with results obtained by other methods elsewhere and with radiation disregarded indicates that this method is applicable and effective. Figures 5, tables 2, references 17 Russian. [8-2415]

UDC 532.546:536.25

VIBRATORY HEAT CONVECTION IN RECTANGULAR CAVITY

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 28 Nov 80) pp 94-99

GERSHUNI, G. Z., ZHUKHOVITSKIY, Ye. M. and YURKOV, Yu. S., Perm

[Abstract] Vibratory heat convection in a cavity caused by oscillations of the latter is analyzed under conditions of weightlessness and unattainable equilibrium. The corresponding system of vector equations describing the velocity-pressure-temperature field is derived from the fundamental ordinary differential equations by averaging. Characteristics of the medium are described by two dimensionless parameters: Grashof number  $Gr$  and Prandtl number  $Pr$ . The problem is solved specifically for high-frequency harmonic oscillations of a flat rectangular cavity. The various modes of convective flow with secondary streams, including quasi-equilibrium modes, as well as transitions from one mode to another and loss of stability are interpreted in terms of thermal flux and thermal flux density as functions of the Rayleigh

number  $Ra = Gr \cdot Pr$  for cavities ranging from a square one to slender ones, with the length-to-width ratio  $L/W = 1-16$ , approaching an infinitely long layer of fluid at the limit with attendant changes in the eddy structure. While the Rayleigh number decreases with increasing relative length of cavity, at a Rayleigh number equal to or higher than  $2 \cdot 10^5$  transition to a metastable state results in steady convective vibrations. Figures 5, references 6: 4 Russian, 2 Western.

[8-2415]

UDC 532.529.5:537

#### FLOW OF ELECTRICALLY CHARGED AEROSOL STREAM AROUND BODIES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 20 Sep 81) pp 71-79

VATAZHIN, A. B., LIKHTER, V. A. and SHUL'GIN, V. I., Moscow

[Abstract] An experimental study was made of flow of an electrically charged aerosol around bodies such as a plate. Major problems in performing the experiment were producing a stream of dispersion with prescribed characteristics measuring its local parameters as well as the small electric charges against a background of intense noise and interference. The equipment included a wind tunnel, an aerosol generator, a nozzle with centrifugal hydraulic injector, a voltage supply for charging the aerosol, a flat plate of stainless steel as target body at ground or any other potential, an oscilloscope and a microammeter for measuring the current in the body, a schlieren system for recording the flow pattern and a grounded permeable mesh near the body for recording the boundary conditions. Experiments were performed with aerosol of solid iron particles and with aerosol of liquid water droplets, each either neutral or charged. Interpretation of the results in terms of theoretical and empirical relations indicates how aerosol and its effect on a target body can be controlled by means of an electrostatic field.

Figures 5, references 15: 12 Russian, 3 Western.

[8-2415]

UDC 532.51:537.2

#### FLOW OF STREAM WITH ELECTRICALLY CHARGED INERTIAL PARTICLES AROUND ELECTRICALLY CONDUCTING SPHERE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 82 (manuscript received 19 Dec 80) pp 21-26

VARENTSOV, O. K., Moscow

[Abstract] An electrically conducting sphere at some potential is placed in a hydrodynamic stream, at the center between two infinitely large parallel

plane electrodes at zero potential. The electrodes are assumed not to perturb the hydrodynamic stream and the current carrying sphere is assumed not to perturb either the electric or the hydrodynamic field distributions in the interelectrode space. The stream carries particles with electrostatic charge moving at a velocity equal to that of the stream near the emitter electrode only. Upon colliding with the sphere or with the collector electrode, these particles either become absorbed or lose their charge. Forces acting on the particles are the electric Coulomb force and the hydrodynamic drag force. Such an electrohydrodynamic flow is analyzed on the basis of corresponding field equations with appropriate boundary conditions for velocity components and electric potential, in cylindrical coordinates with the x-axis through the center of the sphere normal to the electrodes. The problem is solved not only for the range of parameters where the trajectories of particles do not intersect but also for the much wider range where they do intersect. In this case several characteristic lines pass through each point and the velocity of particles becomes indeterminate. Two disperse phases must then be considered, passing above and under the sphere respectively, with necessary additional boundary conditions provided by the flow symmetry. An interesting related problem is that of a particle stream striking a sphere with attendant partial entrainment. This is illustrated here in the case of a sphere at ground potential. The author thanks A. B. Vatazhin for assistance. Figures 3, references 7 Russian.  
[8-2415]

UDC 539.3:534.1

SCATTERING OF SOUND BEAM BY ELASTIC SPHERICAL SHELL IN WATER

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 14 Apr 80) pp 111-113

POROKHOVSKIY, V. V., Institute of Application Problems in Mechanics and Mathematics, L'vov

[Abstract] The echo signal reflected by a surface segment of a thin elastic spherical shell in water after incidence of a sound pulse propagating within a slightly divergent conical beam is analyzed on the basis of the appropriate pressure equation in the Heaviside function, water being regarded as an incompressible nonviscous fluid and the beam axis assumed to be passing through the center of the sphere. The wave motion of the shell is described according to a linear Timoshenko-type theory. Solution of the problem with aid of Fourier integral transformation and by separation of variables yields the echo signal in the form of a series in products of spherical Bessel functions and Legendre polynomials. Typical waveforms of the echo signal have been calculated numerically for shells and incident signals with various values of characteristic parameters. Figures 2, references 9: 7 Russian, 2 Western.  
[16-2415]

ACTION OF WEAK SHOCK WAVES ON MEMBRANE SEPARATING TWO ACOUSTIC HALF-SPACES

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 21 Apr 81) pp 42-48

KUBENKO, V. D. and MOSEYENKOV, Yu. B., Institute of Mechanics, UkrSSR Academy of Sciences

[Abstract] Action of spherical and cylindrical shock waves on a thin membrane separating two half-spaces occupied by acoustic media is analyzed. Each half-space is filled with a compressible fluid characterized by density, wave potential, and acoustic velocity. Pressure and membrane deflection are determined from the equation of vibrations. Perturbations in both fluids are determined from the wave equation for each, in the acoustic approximation, the boundary conditions being impermeability of the membrane on both sides and complete decay of perturbations at infinity. Pressure transients are calculated for the general case as well as for the special cases of two identical fluids and no acoustic medium on the other side. Figures 4, references 9: 8 Russian, 1 Western.  
[16-2415]

MECHANICS OF SOLIDS

UDC 539.3

STABILITY OF SPHERICAL SANDWICH SHELL

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 8, Aug 82 (manuscript received 20 Oct 81) pp 32-35

[Abstract] Stability of a spherical sandwich shell under uniform external pressure is analyzed, applying Timoshenko hypotheses to the transversely-isotropic outer layers and the three-dimensional linearized theory of elastic stability to the transversely-isotropic filler layer. The median surfaces of both outside shells do not coincide with their respective surfaces of contact with the filler between them. The analysis is based on equations of stability for shallow shells in forces and bending moments. Forces and bending moments are related to displacements, boundary conditions are defined for the state of perturbation, and perturbations of forces and moments are calculated with aid of the asymmetric Kirchhoff tensor. The problem is solved for an axisymmetric mode of stability loss, with displacements expressed in the form of power series. The result yields the dependence of critical load on geometrical and mechanical parameters of the three component shells. Article was presented by Academician A. N. Guz', UkrSSR Academy of Sciences. Figure 1, table 1, references 6 Russian.  
[14-2415]

UDC 534.012

PARAMETRIC INSTABILITY OF TRANSVERSE VIBRATIONS OF STRING WITH PARAMETERS VARYING ACCORDING TO TRAVELING-WAVE LAW

Novosibirsk ZHURNAL PRIKLADNOY MEKHANIKI I TEKHNICHESKOY FIZIKI in Russian No 3, May-Jun 82 (manuscript received 10 Mar 80) pp 163-169

VESNITSKIY, A. I. and LYAKHOV, A. F., Gorkiy

[Abstract] Buildup of wideband pulse vibrations is treated as parametric instability of the vibration process. In the simplest case of a one-dimensional

system such as a string this instability is considered assuming the system to be linear, with infinite buildup of vibration energy, and defined as one of the first kind when the amplitude increases without mode transformation or of the second kind when the amplitude increases with attendant continuous compression of the wave profile. First analyzed is the theoretical case of an infinitely long string with parameters varying according to the traveling-wave law and with continuous amplification of vibration waves accompanied by endless twisting of their profile. Next analyzed is the most practical case of such a string of finite length with parametric instability of the second kind. Energy loss and instability regions are determined in each case with either "synchronous" or "asynchronous" waves propagating; also established is the condition under which the family of broken-line pulse waves produced by successive reflections at both string ends becomes periodic. Figures 4, references 13 Russian.

[10-2415]

UDC 539.374

#### ELASTOPLASTIC TWISTING OF ECCENTRIC TUBES

Novosibirsk ZHURNAL PRIKLADNOY MEKHANIKI I TEKHNICHESKOY FIZIKI in Russian  
No 3, May-Jun 82 (manuscript received 14 Apr 81) pp 150-156

BYKOVTSEV, G. I. and ZEBRIKOV, V. P., Kuybyshev

[Abstract] The problem of elastoplastic twisting is solved for eccentrically circular tubes, essentially doubly-connected regions under torsion, by a modification of the perturbation method. The stress function is stipulated in the elasticity zone and the yield criterion is stipulated in the plasticity zone along both outer and inner contours is described in accordance with the Bredt theorem. The solution to the corresponding differential equations is sought in the form of series and obtained upon reduction of the problem to a sequence of partial ones. The result agrees with the solution to exact equations in theory of elasticity and in theory of plasticity for the respective regions. Figures 2, references 10: 7 Russian, 3 Western.

[10-2415]

UDC 539.74

FRAGMENTATION OF SPHERICAL SHELL DURING FRACTURE

Novosibirsk ZHURNAL PRIKLADNOY MEKHNICKI I TEKHNICHESKOY FIZIKI in Russian  
No 3, May-Jun 82 (manuscript received 20 Apr 81) pp 125-132

SERIKOV, S. V., Chelyabinsk

[Abstract] Fracture of a hollow metal sphere under variable internal pressure or in an initial velocity field is analyzed, assuming an incompressible isotropic shell material with viscoplastic properties. Equations of continuity and motion for a continuous medium are formulated in spherical coordinates, taking into account central symmetry of the problem, with appropriate dynamic and kinematic boundary conditions. They are solved for two modes of transient expansion, corresponding respectively to motion from rest under detonating internal pressure and to inertial motion in a velocity field without internal pressure, leading to fracture in each case. The solution involves determining the variation of boundaries (inside and outside radii) in time, which is done for a thin-walled shell by reduction of the corresponding Cauchy problem to an Abel equation of the second kind. The results of calculations are compared with available quantitative experimental data on the fragmentation process, namely number and size of fragments as well as time to fracture under various loads, for several metals (copper, titanium, zinc, Duralumin). Figures 2, tables 3, references 15: 13 Russian, 1 Polish, 1 Western.  
[10-2415]

UDC 531.36

STABILITY OF STEADY MOTION OF SOLID BODY CONTAINING ELASTIC SHELL WITH  
SLOSHING LIQUID

Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 46, No 4, Jul-Aug 82  
(manuscript received 24 Jun 81) pp 543-552

RUBANOVSKIY, V. N., Moscow

[Abstract] A solid body containing a cavity in the form of a closed thin elastic shell partly filled with a fluid is considered and its motion in a conservative potential force field is analyzed, assuming negligible surface tension in the fluid. Steady constraints on the body allow it to rotate about one axis of an inertial rectangular system of coordinates, but forces acting on it do not produce a bending moment about this axis. A movable auxiliary rectangular system of coordinates is introduced, with axes parallel to corresponding principal central axes of inertia of the body in the undeformed state. Equations of steady motion are derived from the principle of possible displacements, with the Kirchhoff-Love hypothesis pertaining to conservation of a normal element applied to the three-dimensional medium of

the cavity-shell. Integration of the displacements gradient yields the pressure in the fluid and an equation for the free surface of the fluid in the steady state. The stability problem is solved, assuming that fluid wets the entire deformable part of the cavity surface. The condition of stability is obtained by minimizing the variable potential and testing its second variation for positive-definiteness, then using the quadrature form with respect to a finite number of variables and the Cauchy-Schwarz inequality.

References 7 Russian.

[15-2415]

UDC 531.011+62-50

#### CONTROLLED MOTION OF ELASTIC BEAM

Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 46, No 4, Jul-Aug 82 (manuscript received 10 Nov 81) pp 587-595

AKULENKO, L. D. and BOLOTNIK, N. N., Moscow

[Abstract] Rotation of an elastic beam of variable cross section about an axis normal to it at the stationary end O is considered, such motion being controlled by an ideally rigid body of small mass exerting torque at the free other end G. The corresponding equations of motion are formulated in a rectangular system of coordinates OXYZ rotating together with the beam in inertial space, with appropriate initial and boundary conditions, supplemented with the equation of momentum change. The problem of control is solved asymptotically: first in the quasi-static approximation for a beam with zero weight and a loading body with constant moment of inertia, an interesting practical case being that of zero initial conditions, then by the method of perturbations in powers of a small parameter for the other extreme of a beam with large flexural stiffness. Figures 2, references 11; 10 Russian,

1 Western.

[15-2415]

UDC 531.391+532.526+532.592

#### STABILITY OF STEADY ROTATION OF CYLINDER WITH SLOSHING INCOMPRESSIBLE VISCOUS FLUID

Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 46, No 4, Jul-Aug 82 (manuscript received 28 Jan 82) pp 578-586

DERENDYAYEV, N. V. and SANDALOV, V. M., Gor'kiy

[Abstract] Rotation of a circular cylinder partly filled with an incompressible viscous fluid about its axis is considered, the latter being axisymmetrically and viscoelastically constrained. The analysis is based on linearized equations for a plane model, also including equations of

translatory motion of the cylinder in the direction normal to its axis and of the fluid as quasi-solid in the same direction, with condition of constant angular velocity for the cylinder, boundary conditions of adhesion at the inside cylinder surface, condition of continuity for stresses and kinematic conditions at the free surface. All equations and boundary conditions are assumed to be linear and homogeneous with respect to deviations from the steady state and, by virtue of symmetry, to be invariant with respect to shift in time ( $t' = t - t_0$ ) and with respect to rotation of the system of coordinates about the cylinder axis through a  $90^\circ$  angle ( $x' = y$ ,  $y' = x$ ,  $z' = z$ ). Two solutions exist, which yield circular precession of the cylinder with fluid. The corresponding hydrodynamic problem is solved on this basis for an infinitely long cylinder, with introduction of Lamb potentials, for calculating the hydrodynamic force and the stability regions in the damping-stiffness plane of variable constraint are determined for steady rotation. A D-curve exists in this plane that separates regions of different degrees of instability. The authors thank G. G. Denisov for participating in the study and discussing the results. Figures 3, references 6: 5 Russian, 1 Western. [15-2415]

UDC 531.36

#### REGULAR PRECESSION OF SOLID OF REVOLUTION ON PLANE WITH FRICTION

Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 46, No 4, Jul-Aug 82 (manuscript received 23 Oct 81) pp 568-572

KARAPETYAN, A. V., Moscow

[Abstract] Motion of a heavy solid body of revolution on a horizontal plane is considered with viscous friction at the last point of contact. The problem is analyzed in a stationary rectangular system of coordinates Oxyz with axes x,y in that plane and axis z oriented vertically upward. The position of the body is defined through Euler angles between those axes and the principal central axes of inertia of the body, with its center of mass lying on the axis of its dynamic symmetry. The equations of motion are written in terms of Lagrange function and Rayleigh dissipation function, after appropriate change of variables. The solution, describing regular precessions without sliding, is examined for stability with respect to perturbations of Euler angles and velocity components. A comparison of this solution with those for motion on a perfectly smooth plane and on a perfectly rough plane reveals that the one-dimensional manifold of regular precessions with friction lies on the intersection of the two two-dimensional manifolds corresponding to the other two cases, this intersection being nonempty when the condition of existence is satisfied. References 8 Russian.

[15-2415]

UDC 531.384

MOTION OF HEAVY HOMOGENEOUS ELLIPSOID ON STATIONARY HORIZONTAL PLANE

Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 46, No 4, Jul-Aug 82  
(manuscript received 14 Apr 81) pp 553-567

MARKEYEV, A. P., Moscow

[Abstract] Motion of a heavy homogeneous ellipsoid on a stationary horizontal plane is analyzed in a stationary rectangular system of coordinates OXYZ with the origin at some point in the plane and the Z-axis oriented vertically upward. The surface of the ellipsoid is described by the canonical equation in a movable rectangular system of coordinates Gxyz with the origin at the center of gravity of the body. The orientation of the ellipsoid is defined through Euler angles and the relations between corresponding coordinates of both systems are described by the matrix of direction cosines. The problem is first solved for a homogeneous sphere moving without sliding, then for an only slightly aspherical triaxial ellipsoid. Periodic solutions are obtained and found to be of two families describing respectively two kinds of motion. Only the one kind generally possible, produced by rolling and spinning, is considered further. On a perfectly smooth plane this motion is perpetual, with regular precessions about the angular momentum vector of constant magnitude and the latter precessing about the vertical axis at constant angular velocity. The range of existence of such a motion is determined, the point of contact between ellipsoid (sphere) and plane is traced on the surfaces of both. The reaction force from the plane is also calculated. The condition of stability for such a motion is determined from the appropriate canonical differential equations with the corresponding Hamiltonian in slow and fast Andoyer variables. Figures 6, references 22: 13 Russian, 9 Western.

[15-2415]

UDC 539.3

FREQUENCY DENSITY OF FREE VIBRATIONS OF THIN ANISOTROPIC SHELL WITH ANISOTROPIC LAYERS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 3, May-Jun 82 (manuscript received 29 Sep 80) pp 171-174

GULGAZARYAN, G. R. and LIDSKIY, V. B., Yerevan; Moscow

[Abstract] Free vibrations of a shell consisting of  $m+n$  anisotropic layers are described by the system of Lagrange-Euler equations for the energy functional according to classical theory, with boundary conditions depending on the end constraints. The frequency density in an asymptotic spectrum is calculated by the Hilbert-Courant method, with aid of a theorem pertaining to the corresponding rectangular  $3 \times 2$  matrix, square  $2 \times 2$  matrix, and two  $2 \times 1$

matrices, the corresponding eigenvalue problem reducing to an eighth-degree polynomial with only eighth-degree and fourth-degree terms. Numerical results are shown for a single-layer orthotropic shell made of boron-plastic with a conical median surface, also for a shell consisting of five orthotropic layers symmetrically spaced relative to the cylindrical median surface with the center layer made of fiberglass plastic and the two pairs of layers on both sides made of carbon-plastic, each shell rigidly clamped at the ends. There appears a range of maximum frequency density and the spectrum of a shell with nonpositive Gaussian curvature includes ultralow frequencies. The authors thank S. A. Ambartsumyan and A. L. Gol'denveyzer for helpful discussions and suggestions, V. V. Vasil'yev, S. A. Lur'ye and A. L. Radovinskiy for consultations on specific problems, and L. V. Markov for plotting the frequency density curves. Figures 2, references 12: 10 Russian, 2 Western.

[7-2415]

UDC 531.8

CONTROL OF WALKING APPARATUS WITH ALMOST WEIGHTLESS LEGS, PART 1:  
CONTINUOUS VARIANT

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 3, May-Jun 82 (manuscript received 25 Dec 80) pp 52-62

LARIN, V. B. and NAUMENKO, K. I., Kiev

[Abstract] A mathematical model of a walking apparatus with almost weightless legs is constructed on the basis of a phase vector and a control vector each having two components: one with phase coordinates corresponding to "heavy" torso and one with velocity coordinates corresponding to "light" legs. A small parameter is introduced characterizing the ratio of leg mass to torso mass, with the effect of leg dynamics on motion of the apparatus then disregarded as the limiting case of weightless legs. The control optimization functional is defined in the continuous variant of this model, first assuming weightless legs and then considering almost weightless legs. The model and the control reduce to a system of differential equations, which are solved in the first approximation for boundary conditions which include finiteness of vectors and matrices in a problem of singular perturbation and with pulse-type regulation. The procedure is applied, for illustration, to a two-legged walking apparatus leaning on one leg at a time. Its motion is described by Lagrange formalism and is programmed for maintenance of posture, to be optimally controlled with minimum actions. Figures 3, references 8: 6 Russian, 2 Western.

[7-2415]

UDC 534.014.4

DAMPING OF VIBRATIONS BY MEANS OF STIFFNESS CONTROL

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 3, May-Jun 82 (manuscript received 11 Nov 80) pp 35-44

LOOSE, H. and HEIMANN, B., East Berlin

[Abstract] A mechanical system is considered that consists of a vibrating mass and a linearly elastic element with controllable time-variable. The characteristics of its free vibrations under both a constant force such as weight and a variable external force are calculated on the basis of the corresponding equation of motion with appropriate initial conditions. Damping of these vibrations by means of stiffness control with repeated alternations is calculated on the basis of the exact solution and then approximate solution for transient forced vibrations under harmonically varying action. A vibration damper designed according to this principle combines advantages of a viscous damper of large-amplitude vibrations and a dry friction damper of small-amplitude vibrations. The amplitude of a dynamic load remains limited even at high frequencies. Figures 6, references 8: 2 Russian, 6 Western.  
[7-2415]

UDC 539.3

LAMB'S WAVES IN PRESTRESSED PLATE MADE OF INCOMPRESSIBLE ISOTROPIC AND LINEARLY ELASTIC MATERIAL

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 16 Apr 80) pp 146-150

YAKOVENKO, M. G., Moscow

[Abstract] Longitudinal propagation of plane periodic waves in a strip of finite width and made of incompressible isotropic and linearly elastic material is considered, this strip being in a uniform initial state of stress and strain under a dead load and the waves having been generated by a steady normal surface load. Analysis and solution of the problem are based on a system of three partial differential equations in two velocities, longitudinal and transverse, and rate of change of hydrostatic pressure. Instantaneous moduli of elasticity are defined according to Cauchy's law of elasticity. Solutions, including the dispersion equation, are obtained for antisymmetric and symmetric modes. Numerical results are shown for Treloar material and specific stress modes. Figures 3, references 5 Russian.  
[6-2415]

UDC 539.3:534.1

EXCITATION OF WAVES IN INTERLAYER BY VIBRATING CYLINDER

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 22 Dec 80) pp 141-145

PEL'TS, S. P. and TSVETYANSKIY, V. L., Rostov-na-Donu

[Abstract] A cylinder is considered standing on a rigid smooth bed, separated from the latter by an elastic interlayer with which it makes frictionless contact. Its upper base is under a harmonically varying axial load. Stresses and strains at the lower base as well as displacements of it producing a wave field in the interlayer are calculated, assuming that separation of cylinder from interlayer is prevented by an additional static pressure load. The solution is based on two conditions: generalized orthogonality of dynamic-state homogeneous solutions for the cylinder and rigid coupling at the lower base of cylinder. Numerical results have been obtained on a computer for various values of mechanical and geometrical parameters. The authors thank I. I. Vorovich and V. A. Babeshko for their attention and suggestions. Figures 2, references 11 Russian.

[6-2415]

UDC 539.3:534.1

THREE-DIMENSIONAL PROBLEMS OF DIFFRACTION FOR PLANE ELASTIC WAVES AT WEDGE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 11 May 81) pp 127-135

SHARIPOVA, S. Kh., Moscow

[Abstract] Diffraction of longitudinal and transverse plane waves by a smooth wedge in an elastic medium is treated as a three-dimensional problem. It is solved by a regular method also applicable to spherical waves, the incident wave assumed to be coming from an infinitely remote point source in a spherical system of coordinates, and the solution is compared with that for spherical waves. The incident wave is described by an appropriate Heaviside function and the latter is integrated over the wedge contour after an expedient change of variables. The problem for a transverse wave reduces, under certain conditions, to that for a longitudinal one and the solution becomes the corresponding acoustic one. The problem for a transverse wave has no solution for incidence angles corresponding to total internal reflection. Figures 2, references 13: 12 Russian, 1 Western.

[6-2415]

UDC 531.39

TRANSLATORY-ROTARY MOTION OF ELASTIC BEAM IN CENTRAL NEWTONIAN FORCE FIELD

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 24 Apr 80) pp 64-68

BOLOTINA, N. Ye. and VIL'KE, V. G., Moscow

[Abstract] Motion of a homogeneous elastic beam inside a weightless cylindrical shell in a Newtonian force field is analyzed, including both translatory and rotary motion. Calculations are based on the integral equations of total energy, angular momentum, and change of potential energy in a rectangular system of coordinates with the origin at the center of attraction in inertial space. Attendant longitudinal strains in the body are treated as in the linear theory of viscoelasticity. The solution, obtained by application of the variational method to change of potential energy, indicates that all finite motion can ultimately become a steady rotation about the center of attraction. An inequality is obtained which, when satisfied, ensures that the beam will not be ruptured by gravitational forces. References 2 Russian.  
[6-2415]

UDC 534

SELF-EXCITED OSCILLATIONS IN SYSTEM WITH ENERGY SOURCE FOLLOWING BOTH  
PERIODIC AND PARAMETRIC PERTURBATIONS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 20 Oct 80) pp 45-63

ALIFOV, A. A., Moscow

[Abstract] Steady-state self-excited oscillations in a system interacting with an energy source are analyzed, specifically in the case of both a harmonic perturbation and a parametric one acting on such a system. The equations of motion for a nonautonomous system are solved in the first approximation, after consideration of several combinations of perturbing and damping forces, with a nonlinear restoring force, including the case of an ideal energy source which does not interact with the oscillatory system through friction. An autonomous system is considered next, after it has been reduced to a nonautonomous one through certain relations between corresponding parameters. The amplitude-frequency-velocity field is calculated, namely the amplitude-frequency characteristics for various fixed velocities and the amplitude-velocity characteristics for various fixed frequencies, on the basis of which the stability regions with respect to characteristics of the energy source and of the load are then established. Figures 7, references 32: 29 Russian, 3 Czech.  
[6-2415]

UDC 531.8

CONTROL OF WALKING APPARATUS WITH ALMOST WEIGHTLESS LEGS: DISCRETE MODEL,  
PART 2

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 4, Jul-Aug 82 (manuscript received 6 Jul 81) pp 36-44

LARIN, V. B. and NAUMENKO, K. I., Kiev

[Abstract] A discrete mathematical model of a walking apparatus is proposed, with a digital computer in the stabilization system, the continuous variant having been proposed earlier (see IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA, No 3, May-Jun 82, pp 52-62). Its motion is described by a difference equation after each step of continuous control has been subdivided into  $h = 1$  equal constant-action intervals. This equation, in the form of a symmetric nonnegative-definite matrix with period  $h$ , is solved for optimum control corresponding to the minimum of the criterion functional in the case of completely weightless legs. For almost weightless legs the difference equation is solved in the first approximation, in terms of matrices containing singularly perturbed elements. The procedure for evaluation of the sequence of matrices  $S(h = k)$  is demonstrated on matrices  $S(h = 1)$  and  $S(h = 2)$  with  $h = 3$  for an arbitrary walking apparatus. The procedure is then simplified for a two-legged walking apparatus through reduction of the problem to evaluation of a periodic sequence of matrices  $S(k)$ . References 6: 4 Russian, 2 Western (1 in translation).

[6-2415]

UDC 539.3

EXPERIMENTAL STUDY OF STABILITY OF CONICAL SHELLS WITH STIFFENERS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 21 Apr 81) pp 85-89

PAL'CHEVSKIY, A. S. and SANNIKOV, Yu. A., Institute of Mechanics, UkrSSR  
Academy of Sciences, Kiev

[Abstract] The effect of discrete orthogonal reinforcement on the stability of thin uniform-thickness shells is evaluated on the basis of experimental data and theoretical calculations. Experiments were performed on conical shells (vertex angle  $\theta = 0.64$  rad, wall thickness  $h = 0.5$  mm, radius of small upper base  $r_1 = 75$  mm, radius of large lower base  $r_2 = 225$  mm) made of rolled sheet of AMg-6M aluminum-magnesium alloy, with 32 stringers ( $6 \times 6 \times 0.5$  mm<sup>3</sup>) and 1, 2, or 3 hoops ( $8 \times 6 \times 0.5$  mm) made of the same material. The shells were loaded by external pressure (through evacuation of the cavity) and by axial compression, separately or simultaneously. The experimental results indicate that discretely reinforced shells have an appreciable additional

load capacity after elastic loss of stability under external pressure or compound load. The theoretical analysis is based on equations of stability derived by Yu. A. Sannikov in accordance with the Kirchhoff-Love hypothesis for the sheath and the Kirchhoff-Klebsch hypothesis for the reinforcement. Calculations, made by the Bubnov-Galerkin method in the monomial approximation of displacements, reveal wave modes of stability loss closely related to the discreteness pattern of reinforcement. Figure 1, table 1, references 6 Russian.  
[16-2415]

UDC 539.3

#### SOLVABILITY OF BOUNDARY-VALUE PROBLEMS IN GENERALIZED THEORY OF ANISOTROPIC SHELLS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 30 Mar 81) pp 78-84

KHOMA, I. Yu., Institute of Mechanics, UkrSSR Academy of Sciences, Kiev

[Abstract] Boundary-value problems for anisotropic shells are considered in a two-dimensional system of curvilinear coordinates and time. Solvability of such problems by the Vekua method is examined, specifically of steady-state problems, with the aid of two theorems pertaining to existence and uniqueness of a solution. According to the results of analysis, such a problem is solvable when and only when the system of external forces applied to the shell is statically equivalent to zero. References 10; 9 Russian, 1 Western.  
[16-2415]

UDC 539.3

#### NUMERICAL ANALYSIS OF STRESSED STATE OF THIN SHELLS WITH CURVILINEAR HOLES

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 13 Oct 80) pp 70-77

GOTSULYAK, Ye. A., GULYAYEV, V. I., PEMsing, K. and CHERNYSHENKO, I. S., Kiev Institute of Structural Engineering; Institute of Mechanics, UkrSSR Academy of Sciences, Kiev

[Abstract] The state of stress and strain of thin shells with curvilinear holes is analyzed on the basis of equilibrium equations according to linear theory with the Kirchhoff-Love hypothesis for isotropic materials. Components of forces and moments are expressed through tensile and flexural strains according to elasticity theory, assuming invariability of transverse fibers,

the relations written in a form invariant with respect to systems of coordinates on the median surface. The calculation procedure involves conformal mapping and algebraization by the method of grids with appropriate finite-difference schemes. There follows a computer-aided numerical solution, shown here for a spherical panel with elliptical, triangular, and square holes respectively, a spherical panel with noncircular curvilinear (elliptical, triangular, square) outer contour and circular hole, a cylindrical shell with circular or elliptical hole, and a toroidal shell with circular or elliptical hole. Figures 3, references 8: 7 Russian, 1 Western.  
[16-2415]

UDC 539.3

#### INTERACTION OF CYLINDRICAL SHELLS AND STIFF BEARINGS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
(manuscript received 7 Apr 80) pp 63-69

SHEVLYAKOV, Yu, A. and RYBNIKOV, M. S., Simferopol State University

[Abstract] The contact problem of an infinitely long circular cylindrical shell containing a fluid and resting, without friction, on or in periodically spaced stiff knife-edge bearings is analyzed according to the classical Kirchhoff-Love theory. The equation for contact pressure, a Fredholm equation of the first kind with a regular kernel, is an ill-conditioned one with an approximate positive definite right-hand side. The integral operator in this equation is proved to be positive definite and the equation is solved through regularization. Contact can be made over a part of a circle only, in which case separation may occur when the arc is short, or over the complete circle with the lateral surface of the unrolling. There exists a combination of parameters corresponding to a uniform pressure distribution over the contact zone and minimum stress concentration. Figures 2, references 10: 8 Russian, 2 Western.  
[16-2415]

## STABILITY OF LAMINATE-WOUND CYLINDRICAL SHELLS WITH BUILT UP INNERMOST LAYER UNDER AXIAL COMPRESSION

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
 (manuscript received 30 Mar 81) pp 119-121

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[Abstract] In production of large multilayer oil and gas pipes by the reeling process with welded on hoops it is possible to build up the thickness of the innermost layer and thus raise the critical level of axial and flexural stresses. Loss of stability occurs in the form of depressions shorter than the distance between hoops. An experimental study of stability loss under axial compression was made on cylinder models of such a pipe. Five turns of titanium alloy VT1-0 tape (modulus of elasticity  $E = 1.13 \cdot 10^{11}$  Pa) were wound on an arbor: inside radius  $r = 90$  mm, thickness of innermost layer  $h_1 = 0.54 \sim 0.6$  mm, thickness of other four layers  $h_2 = 0.34$  mm, length of shell  $L = 180$  mm equal to distance between consecutive hoops. Each shell was reinforced with a single longitudinal welding seam and welding spots at the edges. The test data yield an approximate method of calculating the critical stresses in such a pipe, assuming free supports along the line. The method is based on a radial deflection

$$w = f \sin \frac{\bar{m}x}{r} \cos \frac{ny}{r} \quad (m - \text{number of}$$

longitudinal half-waves,  $n$  - number of circumferential half-waves,  $\bar{m} = \pi mr/L$  and on the solution to the stability problem according to the linear Timoshenko model, with zero increment of total potential energy corresponding to a state of unstable equilibrium. The results are compared with those pertaining to real four-layer cylindrical shells with double-thickness innermost layer for pipelines. Figure 1, tables 2, references 2 Russian.

[18-2415]

## VIBRATIONS OF CIRCULAR CYLINDER CAUSED BY KINEMATIC EXCITATION OF BASES

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 8, Aug 82  
 (manuscript received 23 Dec 80) pp 35-41

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[Abstract] Axisymmetric vibrations of a circular cylinder following kinematic excitation of its bases symmetrically relative to its center plane are analyzed in the three-dimensional formulation with mixed boundary conditions for stresses and displacements. The solution to the corresponding equation of

motion satisfies two of those boundary conditions as identities and reduces the other two to an infinite system of equations from which the state of stress and strain can be determined with the aid of asymptotic expressions. A finite part of the frequency spectrum is considered and the dependence of natural frequencies on the relative cylinder length is established according to this three-dimensional theory and, for comparison, according to the approximate elementary beam and dynamic deformation theories. Figures 3, references 7: 5 Russian, 2 Western.  
[16-2415]

UDC 531.391

MOTION OF FLEXIBLE COUPLINGS INCLUDING WAVE PROCESSES AFTER IMPACT BY RIGID BODY

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
(manuscript received 24 Sep 81) pp 92-98

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[Abstract] Motion of a flexible membrane and a flexible filament after transverse impact by a rigid blunt cone and by a rigid blunt wedge, respectively, is analyzed as a supersonic process. The wavefront separating the region of sliding and the region of sticking is determined from the corresponding equation of motion for the condition that the slip force dominant in the region of sliding and the friction force dominant in the region of sticking balance at the boundary between both regions. The flexible coupling is assumed to be infinitely long in the case of a filament and infinitely large in the case of a membrane, the pressure on either being normal and uniformly distributed. A solution is obtained for an elastic filament or membrane and for elastoplastic ones. The results indicate that, with the same friction coefficient in both regions, the region of sticking shrinks to the tip of the striking body independently of the vertex angle and the velocity of this body, also of the pressure exerted by the ambient medium. Figures 2, references 6 Russian.

[18-2415]

UDC 539.3:534.1

STABILITY AND OPTIMAL DESIGN OF PLATES WITH REINFORCING MEMBERS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
(manuscript received 25 Oct 79) pp 69-74

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[Abstract] Studies made during the 1973-80 period concerning optimal design of reinforced panels for stability, also concerning coupled modes of stability loss in composite panels and racks, are reviewed on the basis of available literature on this subject. Items requiring further study are, according to the analysis of these publications, relations between the many possible modes of stability loss, statistical characteristics of initial shape irregularities and effect of various forms of such irregularities on the subcritical behavior of panels, effect of residual stresses and their distribution on the load capacity of panels, effect of geometrical and physical nonlinearities on the yield strength of the material and the supercritical behavior of panels, and probabilistic approach to design optimization and solution of stability problems taking into account random deviations of geometrical dimensions and material properties. References 59: 14 Russian, 45 Western.

[18-2415]

UDC 620.1.05:624.074.4

ACTION OF LOCAL LOAD ON CYLINDRICAL FIBERGLASS PLASTIC SHELL

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
(manuscript received 10 Feb 81) pp 63-68

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[Abstract] An experimental study was made of deformation of thin-walled cylindrical fiberglass plastic shells under a normal load uniformly distributed over a small rectangular area on the lateral surface. All shells had an inside radius  $R = 80$  mm and a wall thickness  $h = 1.30$  mm, their length-to-radius ratio  $L/R = 1, 2, 3, 4, 5$ . The special-purpose machine for producing a local load included a stationary cross-arm and a movable cross-arm on a base plate and hydraulically driven plungers with interchangeable tips striking the shell surface at spots periodically spaced around the circumference. Fifteen shell specimens were tested in sets of three with any given  $L/R$  ratio. They were first loaded twice with a pressure of  $150 \cdot 10^4$  N/m<sup>2</sup> and unloaded each time for conditioning of the hydraulic compression device, and then loaded over  $10 \times 10$  mm<sup>2</sup> areas in  $60 \cdot 10^4$  N/m<sup>2</sup> steps. The data on deflections as well as axial and circumferential displacements at a loading pad and at various distances from it have been evaluated statistically and also theoretically according to a Timoshenko-type model for a material with low stiffness

in shear. The results show how relative deflection  $W/h$  on the inside surface at the center of a loaded area depends on the magnitude of the load and on the relative length  $L/R$  of a shell. They also reveal a "beam effect" deflection as the relative length increases. The theory yields underestimates of deflection as the relative length increases. The theory yields underestimates of deflection here, the difference being most appreciable (5-7%) for small deflections ( $W/h < 0.5$ ) of short shells ( $L/R < 3$ ) and decreasing for longer shells, as does the classical Love power-law theory. Figures 5, references 5 Russian.

[18-2415]

UDC 539.3

#### CLOSED SHELLS OF REVOLUTION WITH PHYSICAL NONLINEARITY UNDER CYCLICALLY SYMMETRIC LOAD

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
(manuscript received 4 Feb 80) pp 57-62

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[Abstract] Closed shells of revolution are considered under cyclically symmetric mechanical surface load and heating, both representable as trigonometric series, with boundary conditions stipulated in analogous form at both ends. The resolvent system of differential equations, taking into account physical nonlinearity, is obtained from the condition of orthogonality. The corresponding boundary-value problem is first linearized and then reduced from two-dimensional to one-dimensional by the Kantorovich method, with subsequent iterations for determining the components of shearing and flexural strains by the method of variable elasticity parameters in successive approximations. The procedure is demonstrated first on a Du-700 compensating steel lens under antisymmetric surface and end loads, then on a toroidal steel shell under an antisymmetric torsional end load alone, under an axisymmetric temperature load alone, and under both simultaneously. Results for the first example indicate that the second approximation, retention of only the first two harmonic components, is sufficiently accurate. Results for the second example confirm that the strains due to the two loads are not additive beyond the elastic range. Figures 3, references 8 Russian.

[18-2415]

## STABILITY OF NONLINEAR VIBRATIONS OF SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
 (manuscript received 19 Feb 80) pp 50-56

GOTSULYAK, Ye. A., GULYAYEV, V. I., DEKHTYARYUK, Ye. S. and KIRICHUK, A. A.,  
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[Abstract] Steady-state solutions to the system of nonlinear equations

$\frac{\partial^2 U}{\partial t^2} + F(U) + \mu P = 0$  describing nonlinear forced vibrations of shells of

revolution are constructed and plotted in the space of states for stability analysis ( $U = (u, v, w)$  displacement vector,  $F = (F_1, F_2, F_3)$  nonlinear vector function whose components are polynomials  $u, v, w$  and their derivatives with respect to  $\alpha$  and  $\beta$  ( $\alpha$ - circumferential coordinate,  $\beta$ - meridional coordinate),  $P = (p_u, p_v, p_w)$  vector of external load varying as  $T$ -periodic function of time  $t$  and  $2\pi$ -periodic function of space coordinate  $\alpha$ ,  $\mu$ - load parameter). The solution to this problem is demonstrated on a shallow spherical shell subtending a central angle of  $30^\circ$  under a uniformly distributed load harmonically varying in time. Amplitudes of deflections at various points, normalized to shell thickness, are plotted as functions of  $p$ , symmetrical waveforms are plotted for several values of  $p$ , and isolines of deflection amplitudes in vicinity of the state with axisymmetric motion accompanied by cyclically symmetric motion are plotted for time  $t = 0$ ,  $t = T/4$  and  $t = T/2$ .

Figures 3, references 5 Russian.

[18-2415]

REFINEMENT OF FUNDAMENTAL RELATIONS IN GENERALIZED SHEAR MODEL FOR  
 NONHOMOGENEOUS SHELLS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 6, Jun 82  
 (manuscript received 18 Jun 81) pp 42-49

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[Abstract] The model for nonhomogeneous shells is considered which, assuming a uniform state of stress and strain of thin-walled elements and without additional kinematic hypotheses, reduces the three-dimensional equations according to theory of elasticity to two-dimensional equations according to theory of shells. This model is refined by inclusion of transverse shearing stresses and the curvature of thin-walled elements. More precise elasticity relations and expressions for the effective constants are derived on this basis for shells not homogeneous across the wall thickness. Only shells of

uniform thickness are considered, but their structure along the normal coordinate is allowed to be arbitrary. Linear equations of equilibrium are written in a curvilinear system of coordinates  $x_1, x_2, x_3$  for a shell loaded uniformly in the direction of two coordinates  $x_1, x_2$ , assuming first a zero static stress  $\sigma_{33}$  and then taking this stress component into account. The results can be easily extended to arbitrarily loaded shells of any geometry, which requires more general expressions for shearing and flexural strains. The results are applicable to practical accurate calculations for engineering structures. This is demonstrated on a cylindrical shell, with displacements expressed in the form of double trigonometric series and with the problem reduced to an eigenvalue problem for each pair of values of wave parameters  $m, n$ . Figure 1, references 10 Russian.

[18-2415]

UDC 539.3

#### PROBABILISTIC ESTIMATE OF NONAXISYMMETRIC STATE OF STRESS OF SHELL STRUCTURE COMPONENTS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 4 Mar 81) pp 124-126

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[Abstract] The nonaxisymmetric state of stress and the load capacity of thin-walled shell components of compound structures are estimated probabilistically, taking into account the random technological spread of geometrical dimensions as well as of material properties and mounting rigidity. The estimate is made by an approximate method used before in the case of a random modulus of elasticity. The probability density distributions of actual stress and transient resistance are determined, after statistical processing of test data, from Taylor series in deviations from mean values of approximating resolvent stress, strain, and displacement functions of random variables  $\beta_i$ . The zeroth-order term of such a Taylor series represents the solution to the corresponding system of differential equations for given boundary conditions and mean values of random variables  $\beta_i$ . The other terms are obtained by successive differentiations with respect to these variables. The resolvent system can be integrated numerically by the Runge-Kutta method with discrete orthogonalization of particular solutions. The procedure is illustrated by a structure consisting of a conical segment and a spherical segment, both of linearly variable thickness, mounted on an elastic Winkler base and loaded nonaxisymmetrically. Figures 3, table 1, references 4 Russian.

[17-2415]

## STATE OF THERMOELASTOPLASTIC STRESS OF SHELLS OF REVOLUTION UNDER NONAXISYMMETRIC LOAD WITH LOADING HISTORY

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
 (manuscript received 21 Sep 81) pp 117-120

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[Abstract] A thin shell of revolution with circumferentially and meridionally varying stiffness is loaded by nonaxisymmetric surface forces while being nonuniformly heated. Its state of elastoplastic stress is analyzed, with loading history and temperature dependence of the material characteristics taken into account. The problem is treated as a geometrically linear one with arbitrary boundary conditions at the parallel edges. It is solved analytically by the method of variable elasticity parameters, according to the theory of simple loading processes. A numerical solution is obtained by the Runge-Kutta method with discrete orthogonalization. Typical results are shown for a truncated conical steel (grade EI-395) shell in an ambient medium with temperatures  $T_1 = 20^\circ\text{C}$  at outside surface,  $T_2 = (600-580e^{-1.5t})$   $(1 + 1/4\cos\theta)$  at inside surface ( $t$  - time,  $\theta$  - angular circumferential coordinate),  $T_3 = 500-480e^{-t}$  at free base, and thermal insulation at rigidly clamped base. Figures 3, references 11 Russian.

[17-2415]

## LOAD CAPACITY OF IMPERFECT CYLINDRICAL GLASS SHELLS UNDER EXTERNAL PRESSURE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
 (manuscript received 11 Dec 79) pp 114-117

ZOLOTAREV, P. F., Institute of Problems of Strength, UkrSSR Academy of Sciences, Kiev; SPIRO, V. Ye., Leningrad

[Abstract] An experimental study of cylindrical glass (grade 13) shells was made to determine the effect of initial shape imperfection on their load capacity under external pressure. Twenty specimens were tested (length 241-600 mm, mean radius  $72.83 \pm 1.27$  mm, mean wall thickness  $4.25 \pm 0.42$  mm, thickness variation  $+(3.0-13)\%$  and  $-(4.0-12)\%$ , ratio of nominal thickness to nominal radius ranging from 0.07 to 0.15). A comparison of the results with calculations based on the strength criterion for ultimate stress and the Flugge relation for critical pressure reveals a difference between theoretical and actual critical pressure ranging from  $-9.5\%$  (understated) to  $+21.0\%$  (overstated), in some cases only within  $\pm 1.3\%$ . Figures 2, table 1, references 5: 4 Russian, 1 Western.

[17-2415]

FREE AND FORCED VIBRATIONS OF CIRCULAR RINGS OF LARGE CURVATURE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 17 Jan 80) pp 80-83

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[Abstract] Free and forced vibrations of a circular ring in its plane are analyzed, assuming the ring to have a large curvature and taking into account internal friction in the material. The corresponding equations of motion with natural boundary conditions are obtained from the Hamilton variational principle and the generalized Hooke law, energy dissipation per cycle assumed to be independent of frequency. The external load is stipulated in a form corresponding to that on stators of electrical machines. The bicubic algebraic equation for free vibrations without friction yields three natural frequencies at which resonance can occur for each order of electromagnetic force wave  $n = 2p$  ( $p$  - number of pole pairs). According to the theory of thin rings, the lowest of these frequencies corresponds to a predominantly flexural mode and the higher two correspond to shearing and tangential modes.

Figures 4, references 8: 4 Russian, 4 Western.

[17-2415]

OPTIMAL DESIGN OF PLATES AND SHELLS WITH PHYSICAL NONLINEARITY TAKEN INTO ACCOUNT

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 21 Jan 81) pp 52-57

BOCHKAREV, V. V. and KRYS'KO, V. A., Saratov Polytechnic Institute

[Abstract] A method of optimizing the design of plates and shells with respect to mass is proposed which takes into account physical nonlinearity. Shallow plates and shells of rectangular planform are considered under a transverse load, with minimum allowable thickness and maximum allowable stress intensity stipulated as constraints. The equations of stressed-strained state are solved by the Vlasov-Kantorovich method with variational iterations. The algorithm involves repeated solution of these equations for successive thicknesses given at intersections of a square grid superposed on the planform with attendant solution of the physical problem for each thickness distribution by the method of variable elasticity parameters according to the theory of small elastoplastic strains. The procedure, simplified with sufficient accuracy by representing the deflection function and the stress function as products of two functions of separate coordinates, has been programmed in FORTRAN for a BESM-6 computer. It is illustrated by the example of a square

nonlinearly elastic plate hinge-supported, rigidly clamped, and with mixed boundary conditions respectively. Optimization is found to result in substantial material economy in the last two cases and in higher load capacity with little material saving in the first case. Figures 5, tables 4, references 9: 8 Russian, 1 Western.

[17-2415]

UDC 539.3

MATHEMATICAL MODEL OF DISCRETE BONDING BETWEEN LAYERS IN STABILITY CALCULATION OF DOUBLE-LAYER CYLINDRICAL SHELL

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 12 Nov 80) pp 46-51

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[Abstract] A mathematical model is proposed for calculating the stability characteristics of double-layer cylindrical shells under axial compression, taking into account incomplete contact between the layers. Such a shell is assumed to consist of two layers so thin that the difference between the radii of their middle surfaces can be disregarded. The layers are bonded together by narrow adhesive strips of thickness much smaller than that of the layers. The kinematics of such a nonhomogeneous shell is described by five characteristic displacement parameters. Its state of stress and strain is described by a system of four equations for forces and moments, strains and displacements. Upon introduction of dimensionless variables and differential operators, these equations are solved for a shell resting at both ends on stiff hoops which allow rotation of the end sections. The mode of stability loss in a shell with uniformly spaced bonding strips is closely approximated by one term of a double trigonometric series. On this basis, the system of equations is solved by the Bubnov-Galerkin method reducing it to a system of linear algebraic equations with unknown coefficients and yielding the critical load. Numerical calculations have been made for an orthotropic shell with Young moduli  $E_1 = 1.5 \cdot 10^5$  MPa,  $E_2 = 4.5 \cdot 10^5$  MPa, shear modulus  $G_{12} = 0.35 \cdot 10^5$  MPa, both layers  $t = 1$  cm thick, and bonding strip  $t_b = 0.1$  cm thick. The results indicate that discreteness of bonding must be taken into account for both welded and glued joints. Figures 4, references 3 Russian.

[17-2415]

UDC 539.3:534.1

PROPAGATION OF AXISYMMETRIC DISPLACEMENT WAVES THROUGH MULTILAYER CYLINDRICAL SHELL

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 9 Jul 81) pp 41-45

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[Abstract] Propagation of axisymmetric waves through a double-layer cylindrical shell is analyzed on the basis of more precise elasticity relations, including  $2h/r$ -terms ( $2h = h_1 + h_2$  total thickness,  $r$ -radius of curvature), than those according to the conventional Kirchhoff-Love and Timoshenko models. Equations of motion and the dispersion equation are derived for the special case of two isotropic layers giving the dependence of dimensionless phase velocity and vibration frequency on wave number. This solution is compared with the solution to the corresponding three-dimensional problem and with the solution based on application of the Timoshenko hypothesis to each layer separately with inclusion of correction factors to account for shear. The proposed method is simpler than the other two and applicable to a wide range of engineering problems. Figures 2, references 10: 7 Russian, 3 Western.  
[17-2415]

UDC 539.3

FORCED OSCILLATIONS OF PIECEWISE-NONHOMOGENEOUS REGULAR MEDIUM WITH SPHERICAL CAVITY

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 7, Jul 82  
(manuscript received 3 Mar 80) pp 23-28

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[Abstract] Deformation of an isotropic regular-laminate half-space consisting of curvilinear layers by a force harmonically varying in time is analyzed in terms of radial displacements and stresses, taking into account central symmetry in the case of a spherical medium and with conditions of continuity stipulated at the layer boundaries. Displacement and stress distributions are evaluated on the basis of numerical solution of the corresponding eigenvalue problem with the use of transfer matrices. Typical results have been obtained for a medium consisting of alternate layers of two materials, with ratio of densities  $\rho_1/\rho_2 = 2$ , ratio of Young moduli  $E_1/E_2 = 20$ , and Poisson ratios  $\nu_1 = 0.30$ ,  $\nu_2 = 0.35$  respectively with various ratios of inside radius to layer thickness at cutoff frequency  $\omega_c^* = 6.28$  ( $N = 1000$  layers) and at frequency  $\omega^* = 0.628$  ( $N = 10$  layers). Figures 4, references 5 Russian.  
[17-2415]

## TESTING AND MATERIALS

UDC 621.822.5

### USE OF SILICIZED GRAPHITE IN HIGH-TEMPERATURE SLIDING BEARINGS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 6, Jun 82 pp 14-16

VYAZANKIN, V. V., candidate of technical sciences, LUKIN, S. A. (deceased), engineer, and MEDVEDEV, L. F.

[Abstract] The performance of silicized graphite in sliding bearings of pumps for circulating distilled water at high temperature was studied experimentally. Static action of distilled water on various grades of graphitic materials under isothermal conditions at successively 150, 200, 250, 300°C under a pressure of 14-16 MPa was tested for 250 hours. The effect was measured in terms of changes in mass, compressive strength and hardness, also in external appearance. The results, despite wide spread and fluctuation of data, indicate that silicized graphite is most stable and thus most suitable for use at temperatures up to 300°C. The same materials were further tested as friction pairs in a special-purpose machine with ambient distilled water at 25-30, 100, 150, 200°C, and again an SG-P — SG-P pair was found to have the most stable physico-mechanical properties. In the final test an axial bearing and a radial bearing, both with SG-P 0.5 pairs, were tested under load; the axial bearing in 590 starts and in a run under 70-80 N/cm<sup>2</sup> for 14,300 h (including 12,260 h at 200°C) at a sliding velocity of 16 m/s, the radial bearing in 83 heatups and in a run at about 300°C and a sliding velocity of 17.3 m/s for 7800 h. The axial bearing was cylindrical, the radial bearing was conical to compensate for difference in thermal expansion coefficients with some sacrifice in tensile strength. The wear rate in both cases did not exceed 10·10<sup>-3</sup> μm/h. Figures 4, references 5 Russian.  
[1-2415]

GENERAL-PURPOSE LABORATORY MAGNET LAB-250

Moscow PRIBORY I TEKHNIKA EKSPERIMENTA in Russian No 4, Jul-Aug 82  
(manuscript received 28 Jun 79, after revision 29 Sep 80) p 236

BIL'DYUKEVICH, A. L.

[Abstract] A general-purpose laboratory electromagnet is available, an improvement of the DuBois version in that the cores together with the coils can be moved closer or farther apart on a ferromagnetic base plate constituting a part of the controllable yoke. The width of the air gap can thus be varied from 0 to 300 mm. The pole shoes are interchangeable to match the yoke configuration. The magnetizing winding consists of 12 50-ohm sections without bobbins, water cooled (4 liters/min) through tubing between coil sections, the modulating winding nests in the interpolar space between the conical tips of both pole shoes. The electromagnet is mounted on a turntable whose rotation can be read accurately within 3'. The maximum magnetic induction at a power of 3 kW ranges from 0.2 T in a 250x30 mm air gap to 3 T in a 60x10 mm air gap. The electromagnet weighs 1200 kg and its overall dimensions are 1200x1100x940 mm. Figure 1,  
[21-2415]

CSO: 1861

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